The development of a modified 2 pair Dichotic Digit test recorded in a South African English Accent

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ABSTRACT

The impact of Central Auditory Processing Disorders (CAPD) on language and communication of children and adults is well documented in research. Several tests and normative data exist to assess and diagnose for CAPD, but these tests are not valid for use in South Africa due mismatch in the language or accent of the test recording and the language spoken in South Africa as well as normative data that were collected in the United States of America. As such CAPD may remain undiagnosed, misdiagnosed or designed management plans may be inappropriate as they arose from invalid tests. This study employed a developmental study design in order to adapt an existing 2-pair dichotic digit test (2-pair DDT) to a South African English accent to better suit the South African context. The study further investigated the effect of accent on dichotic digit test performance by comparing the performance of South African adults on the newly adapted South African accent 2-pair DDT and the existing 2-pair DDT, specified by the Department of Veteran Affairs (DVA), using a Wilcoxon-signed ranked test. Lastly, the study collected normative data for the 2-pair DDT that can be used in South Africa.

The study successfully used a developmental study design to produce a South African accent 2-pair DDT that meets the international specifications as outlined by the DVA. A Wilcoxon-signed ranked test showed that South Africans performed better on the South African accent 2-pair DDT than on the DVA specified test. The latter finding was supported by qualitative reports from the participants who found the DVA specified 2-pair DDT stimuli to be more difficult to listen to as compared to the South African accent test. Furthermore, the study produced preliminary normative data for the South African accent 2-pair DDT that met international standards and may be used to score 2-pair DDT performance.

The successful use of the developmental study design to adapt the 2-pair DDT shows promising possibilities as a systematic process for adapting or developing tests that are more contextually appropriate for various contexts.

Key words: Central auditory processing disorders, dichotic digit test, South African English accent, developmental research design

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LIST OF ABBREVIATIONS

Term	Definition
AAA	American Academy of Audiology
AP	Auditory Performance
ABR	Auditory Brainstem Responses
ADHD	Attention Deficit/Hypersensitivity Disorder
AMLR	Auditory Middle-Latency Responses
APD	Auditory Processing Disorders
ASHA	American Speech-Language-Hearing Association
CANS	Central Auditory Nervous System
CAPD	Central Auditory Processing Disorders
CHAPS	Children's Auditory Performance Scale
DD	Dichotic Digits
DDT	Dichotic digits test
DVA	Department of Veterans Affairs
MLD	Masking level difference
MMN	Mismatch Negativity
PSI	Paediatric Speech Intelligibility
RASP	Rapidly Alternating Speech Perception
SA	South Africa/ South African
SAA	South African Accent
SCAN	Test for auditory processing in children
SSI ICM	Synthetic Sentence Identification with Ipsilateral Competing Message
SRT	Speech Recognition Threshold

CHAPTER 1 INTRODUCTION

Central Auditory Processing Disorders (CAPD) refers to difficulties in the perceptual processing of auditory information in the central nervous system (CNS) as demonstrated by poor performance in one or more auditory skills (American Speech-Language-Hearing Association/ASHA, 2005; Emanuel, Ficca & Korczak, 2011). The condition is reported to affect seven percent of children in the United States of America and United Kingdom (Tawfik, Hassan & Messallamy, 2015; Keith, Purdy, Baily & Kay, 2019) and as high as 23% among United States adults (Keith, Purdy, Baily et al., 2019). It is known to negatively impact language and listening behaviour even when the patient has normal audiogram results (Wilson, 2018). CAPD can affect learning and social function in children, and in adults it can affect their work and social life (ASHA, 2005; Chermak & Musiek, 2007; Obuchi, Ogane, Sate & Kaga, 2017; Rodden, 2019. Given the potential impact of CAPD it is imperative for it to be identified and managed as early as possible.

While CAPD assessment tools and normative data have been developed to diagnose the condition, the existing resources cannot be used universally they are not applicable to all contexts and population groups. (South African CAPD Taskforce, 2000; Pascoe & Norman, 2011). English test materials that were created in the United States of America are not valid in contexts like South Africa, where there are eleven official languages (South African CAPD Taskforce, 2000; Pascoe & Norman, 2011). This is due to a mismatch in the language and even accent of the assessment recordings and that of the South African population. As such the use of the existing test materials in South Africa could lead to CAPD being undiagnosed, over-diagnosed and could even lead to its mismanagement.

To address the issues surrounding the applicability of CAPD assessment tools and normative data in South Africa a CAPD Taskforce was developed in 2000. The Taskforce recommended a low linguistically loaded (assessments that make use of numbers and tones) CAPD protocol for CAPD assessment in South Africa. However, research shows even the recommended protocol is not valid in the context of South Africa.

Given the lack of contextually appropriate CAPD tests in South Africa, the present study used a developmental study design to adapt a 2-pair dichotic digit test (2-pair DDT) to better suit the needs of the South African context, by re-recording it in a South African English accent. The study also investigated if accent has an effect on 2-pair DDT

performance by comparing 2-pair DDT scores obtained from the newly adapted test and the American based test specified by the Department of Veteran Affairs (1997). The study used a cross-sectional comparative research design to achieve the second aim of the study. The last aim of the study was to generate preliminary normative data for the 2-pair DDT that may be used during CAPD assessment in South Africa.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter presents the history of Central Auditory Processing Disorders (CAPD), a literature review, the problem statement and the rationale for the current study. It does so by presenting a brief history of CAPD, outlining the main skills of auditory processing (AP), CAPD and its assessment. It then describes the test involved in CAPD assessment, normative data used to diagnose CAPD, the application of the latter as well as their limitations within South Africa and similar contexts.

2.2 History of CAPD

CAPD or alternatively Auditory Processing Disorders (APD) refers to difficulties in the perceptual processing of auditory information in the central nervous system (CNS) as demonstrated by poor performance in one or more auditory skills such as sound localisation and lateralisation or auditory pattern recognition (ASHA, 2005; Emanuel, Ficca & Korczak, 2011). There is controversy regarding whether to call it CAPD or APD (ASHA, 2005; Wilson, 2018); however, this research study does not focus on the nomenclature debate. It acknowledges the definition by ASHA (2005) and Vermiglio (2014) that emphasises the role of the central auditory nervous system (CANS) in auditory processing and lesions that lead to CAPD. Therefore, the term CAPD is used to refer to the condition under investigation.

The first documentation of CAPD was reported by Myklebust (1954) when he noted a group of children who presented with listening difficulties despite having normal pure-tone thresholds (ASHA, 2005; American Academy of Audiology (AAA), 2010; Wilson, 2018). His first postulation was that the condition could be explained by an auditory agnosia caused by damage to the auditory cortex, particularly the receptive areas (ASHA, 2005; Wilson, 2018). Secondly, he postulated a perceptual disturbance preventing normal listening behaviour where the child would hear but fail to structure the auditory word and derive meaning (ASHA, 2005; Wilson, 2018).

As cited by Wilson (2018) and Jagger (2009), researchers like Broca, Wernicke, Jackson, Head and Freud built on these findings by providing brain images that found a link between brain injury and disturbances of receptive and expressive language. It was then theorised from the latter findings that if a test were developed and it identified reduced performance in an auditory skill associated with a specific brain lesion, then that test could accurately predict auditory performance and by extension be used for the diagnosis of CAPD (Jager, 2009; Wilson, 2018).

Such behavioural tests, which include both speech and tonal stimuli, have been developed in America for the assessment of CAPD (Department of Veterans Affairs [DVA], 1998). The tests assess the following skills that are key to AP (ASHA, 2005):

- sound localisation and lateralisation
- auditory discrimination
- auditory pattern discrimination
- temporal integration and separation
- temporal ordering
- temporal masking
- auditory performance in competing acoustic sound signals
- auditory performance with degraded acoustic signals.

Reduced performance in one or more of these skills leads to a condition known as CAPD (ASHA, 2005; Cameron, Glyde, Dillon, King & Gillies, 2016).

2.3 Impact of CAPD

The impact of CAPD is often seen in school-aged children through difficulties in learning, speech, language and social functions (ASHA, 2005; Chermak & Musiek, 2007). In addition to the aforementioned difficulties, children with CAPD are known to display behavioural, emotional and social difficulties. The effects of CAPD can also be noticed in adults, particularly if it is acquired due to brain injury, consequent to aging or if the initial CAPD was undiagnosed and unmanaged at an earlier stage (Bellis, 2003; Emanuel et al., 2011; Obuchi, Ogane, Sate & Kaga, 2017). CAPD can cause difficulties in language comprehension and communication among adults (Bellis, 2003; Obuchi et al., 2017; Rodden, 2019). Additionally, CAPD may manifest as poor listening skills, poor reading

comprehension or miscommunication that causes trouble in various aspects of life: family, work and friends (Bellis, 2003; Obuchi et al., 2017; Rodden, 2019). At work, CAPD can lead to trouble carrying out or even remembering multi-step instructions (Obuchi et al., 2017; Rodden, 2019). People like waiters or construction workers who work in noisy workplace areas may find themselves having trouble following instructions, taking down orders or remembering items (Bellis, 2003: Obuchi et al., 2017; Rodden, 2019). This can potentially lead to poor service and termination of employment. Miscommunications due to CAPD have been found to cause secondary effects such as mental health problems (Obuchi et al., 2017) and social isolation, which can lead to social and emotional difficulties. It can heavily affect adults, leading to a poor quality of life. Early and accurate identification of CAPD is needed for early management which may reduce the adverse effects of the condition in both children and adults (ASHA, 2005).

2.4 CAPD assessment

According to ASHA (2005), the assessment for CAPD involves assessing the integrity of the CANS and determining the presence of CAPD. This involves use of a test battery to assess different aspects of auditory processing using both verbal (word and sentences) and non-verbal stimuli (click, numbers and tones) (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; ASHA, 2005; Fouche-Copley, Govender & Khan, 2016). By including both verbal and non-verbal stimuli, the clinician is able to gain greater insight into the integrity of the CANS and provide a more refined diagnosis of CAPD (ASHA, 2005; AAA, 2010). According to Chermak and Musiek (2007) and Bellis (2011) the tests that assess auditory skills are categorised based on the processes they assess, resulting in four main categories:

1. Dichotic listening: tests that assess dichotic listening, the ability to process different phase differences.

2. Binaural interaction tests for binaural interaction, the ability to process different but complementary information presented to both ears either sequentially or simultaneously.

3. Monaural low redundancy tests assess the ability to achieve closure or fill in missing auditory information and correctly discriminate the stimulus even when part of it is distorted or missing.

4. Temporal processing tests for assessing the ability to make a discrimination based on the timing order or pattern of the stimulus

As the current study focused on a dichotic listening test the test of interest and category will be explored further below while additional details of all the four test categories can be found in Appendix L. The current study acknowledges the anatomical and physiological processes involved in dichotic listening. According to Kimura (1967) the contralateral pathways involved in dichotic listening are stronger, numerous and supress the ipsilateral pathways. That is to say information presented to the right ear is processed in the left temporal lobe and that from the left ear in the right temporal lobe. However, when dichotic listening tests require verbal labelling of stimulus, a process housed in the left hemisphere, information from the left ear will travel to right hemisphere and cross over to the left hemisphere via the corpus callosum to left hemisphere for processing. As the right ear has a direct contralateral connection to the left hemisphere than the left ear this results in right ear scores during dichotic listening tasks being higher. This is known as a right ear advantage.

The test adapted in this is study is the Dichotic Digits Test (DDT). In this test two different digits are presented simultaneously, one to each ear (dichotically). The digits used in the test range are from 1 to 10 with 7 being excluded. The test may be used as binaural interaction test or a binaural separation test. In binaural integration, the listener presents the numbers back in any order while in binaural separation, the listener reports which number pair was presented to each ear.

It worth mentioning that no universally accepted CAPD test, diagnostic test battery or criteria exists but the tests that are available and used are those that have proven to have the best sensitivity and specificity (British Society of Audiology, 2017; Chermak, Iliadou, Bamiou & Musiek, 2018). When assessing for CAPD, the test battery must be individualised and tests must be selected from the list provided in Appendix L by using information gathered in the case history and from the referring complaint (ASHA, 2005; AAA, 2010). In so doing, CAPD can be accurately identified and a specific management plan can be developed to meet the individual's needs (ASHA, 2005; AA, 2010). However, these tests were tailor-made for the American English-speaking population and as such, the accent and even the language of most of the tests are not appropriate for use within the South African context (South African CAPD Taskforce, 2000; South African CAPD

Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; Fouche-Copley et al., 2016). This has led to only five of the listed tests being recommended as applicable for CAPD assessment in South Africa (South African CAPD Taskforce, 2001). As a result, many of the CAPD assessments carried out in South Africa are not individualised, they do not contain sentence stimuli as recommended by ASHA (2005), and therefore the needs of patients with CAPD are currently not being met (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; Fouche-Copley et al., 2016). See the sections 1.5 and 1.6, below for a more detailed discussion on the applicability of CAPD tests in South Africa.

Additionally, the assessment of CAPD should involve the use of tests that are high in sensitivity and specificity (ASHA, 2005). Sensitivity refers to a test's or a tool's ability to identify a disorder or pathology when it is truly present (ASHA, 2005). Specificity refers to the ability of a test to correctly identify the absence of a disorder or pathology being investigated when it truly absent (ASHA, 2005). By achieving good sensitivity and specificity, the clinician can be confident in a diagnosis and develop an appropriate management plan to benefit an individual's needs. Given that the current CAPD assessment tests are not valid for use in South Africa, this cannot be achieved (South African (SA) CAPD Taskforce, 2000; SA CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; Fouche-Copley et al., 2016).

2.5 The validity of CAPD assessment tests

The tests to assess for CAPD can be found in the Tonal and Speech Material for Auditory Perceptual Assessment Disc 1.0 that was later upgraded to the Tonal and Speech Material for Auditory Perceptual Assessment Disc 2.0. These discs have the same test recording with the exception that (1) dichotic chords with simultaneous onsets, and (2) dichotic chords with a 90 ms lag in the left channel were removed from the disc 2.0 (DVA, 1998). Instead, the following test recordings were added (1) two Tracks of 25, 2-pair dichotic digits (DD), (2) two Tracks of 25, 3-pair DD, and (3) two Tracks of 54, randomized 1-, 2-, and 3-pair of DD (DVA, 1998). The number of frequency and duration tone pattern stimuli were reduced from 60 ms in Disc 1.0 to 30 ms in Disc 2.0 (DVA, 1998).

Ninety-five percent of the test material in Disc 2.0 was recorded in an American English accent and therefore have less validity in contexts that use a different language or even a

different English accent (DVA, 1998; SA CAPD Taskforce business plan; SA CAPD Taskforce business plan 2, 2001; Mukari et al., 2006; Bantwal, 2011). Countries like India, Malaysia, Iran and Canada have all reported issues surrounding the lack of context specific assessment materials and normative data for CAPD testing (Bantwal, 2011; Jutras, Mayer, Joannette, Carrier & Chenard, 2012; Shahmir, Hajiabolhassan, Khani, Tahaei, & Jalaie, 2015; 2018; Mukari, Keith, Tharpe & Johnson, 2009; Pedersen, Dahl-Hansen, Christensen-Dalsgaard & Brandt, 2017; Selvaraj et al., 2018).

A study by Bantwal (2011) reports that India has few centres that offer CAPD services. CAPD services are lacking in the rural areas of India where the majority of the population lives. Furthermore, there is a lack of resources to assess for CAPD. This includes specialised CAPD equipment and test material. Only language free tests are used in India for the assessment of CAPD.

Selvaraj et al. (2018) responded to the lack of appropriate CAPD tests in India by developing a dichotic word test for Tamil speaking children. They selected 200 monosyllabic words from schoolbooks that were familiar to 7–12-year-olds. They then presented the words to 15 professionals who picked the most familiar words to be included in the test. Only 100 words were used in the test, which was recorded using PRAAT 4.5.16 software. Three recordings were made and edited to create the final product, which was a Tamil dichotic word test that could be used during CAPD testing. Their study showed the value of studies aimed at adapting a CAPD test and that it was possible to do so. Their study further displayed the right ear advantage that was first reported by Kimura (1961). The study also showed no statistically significant differences between male and female dichotic listening scores.

Mukari et al. (2006) identified the lack of a single and double dichotic digit test in Malaysia. In response, they developed both the single and double dichotic digit test that include the numbers one to eight in the Malay language. A male speaker was chosen for the recording which took place in a sound studio. Five recordings were made from which the clearest recordings were picked to be included in the tests. The Cool Edit Pro 2.0 was used to edit the digit signal to average levels of 0 VU meter and the duration of each word was around 600 ms. Upon testing participants, they found that the double DDT had a higher right ear advantage and test-retest reliability than the single DDT. They concluded that the double DDT was more clinically applicable. A similar study was done by Rajabpul, Hajaiblohasan,

Tahai and Jalei (2014) and Shahmir et al. (2015) with the major difference being that the tests were recorded in the Persian languages for the context of Iran. They found that the use of the Persian double dichotic digit produced high mean values and had a high reliability. They further concluded that based on the high reliability, the test was suitable to use in clinical testing. These studies show that adapting tests can help improve context specific CAPD test batteries.

The issues surrounding the validity of CAPD tests have also been reported in developed countries like Canada and Denmark (Jutras et al., 2012; Pedersen et al., 2017). Both countries have had to develop context specific assessments and test batteries for CAPD. This shows that the validity of CAPD test is questioned even in developed countries, adding to the need to contextualise CAPD tests. Most importantly, it shows a need for a developmental process for CAPD tests that can be applied to any CAPD test, potentially in any context.

The studies discussed above report on how specific tests were developed. All the studies conclude that the respective tests that were developed or adapted are more appropriate for use in their specific context. It worth noting that the studies do not cite or produce a process of adapting tests to meet the needs of a specific context. The developmental processes described are brief and specific to the study's test of interest. The current study outlines the developmental process of adapting the 2-pair DDT that can potentially be applied to adapt or develop more CAPD tests.

2.6 The validity of CAPD assessments in South Africa

In South Africa, the validity of the existing tests for CAPD becomes more questionable considering that South Africa has 11 official languages (South African CAPD Taskforce, 2000; Saleh et al., 2003; Campbell & Wilson, 2003). Furthermore, even though English is one of the official languages spoken in South Africa, the South African English accent is different from that of the American accent used in the existing CAPD test material (South African CAPD Taskforce, 2000; Lass, 2002). The differences in accent are primarily due to the different vowel pronunciations (Lass, 2002). The American accent carries long vowel pronunciations from the 17th century (Lass, 2002). An example is /a/ which is longer and is pronounced at the front of the tongue in the American accent while in the South African accent, /a/ is shorter and is pronounced further back (Lass, 2002). This is evident when

pronouncing the word /bath/ with the two accents. Furthermore, the American accents is rhotic, i.e. /r/ is pronounced in a word that has a consonant following it such as in thirty (Lass, 2002). In the South African accent, the /r/ is silent. This presents a mismatch between the accent of the test recordings and that of the South African population. In a test, this could influence the testee's ability to correctly perceive the test stimuli when they are presented in an American accent, thereby affecting the test validity and ultimately leading to false positive test results (Saleh et al., 2003; Campbell & Wilson, 2003; Bantwal, 2011; Fouche-Copley et al., 2016). False positive results and misdiagnosis are a big concern as they could lead to improper management of CAPD while the actual pathology remains untreated and patient still suffers from its effects. Misdiagnosis may also lead to over-referral of CAPD cases. This would place a burden on the already scarce resources in South Africa's health care system (Norman & Pascoe, 20011; Fouche-Copley et al., 2016). In addition, the client with a misdiagnosis would have to use resources they do not have, for example, transport to travel far distances to get unnecessary management for a CAPD (Norman & Pascoe, 2011). A false positive may also cause emotional distress to client and the family who would be led to believe they have a problem with their auditory processing which they do not have (Khairi et al., 2011). The development of appropriate tests could help negate this effect.

South Africa not only lacks contextually appropriate test material but also context specific normative data (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; Fouche-Copley et al., 2016). The current normative data used to assess for CAPD are based on studies that collected data from American participants (SA CAPD Taskforce business plan 2; 2001; Bellis, 2003; Saleh et al., 2003; Campbell & Wilson, 2003). The aforementioned normative data are specific to the United States of America and are not valid for use in South Africa (CAPD Taskforce business plan 2; 2001; Bellis, 2003; Saleh et al., 2003; Campbell & Wilson, 2003).

The lack of context specific tests and normative data has been a long-standing concern for South African-based audiologists/practitioners in the field (Fouche-Copley, Govender & Khan; 2016). So much so that a group of South African-based health professionals banded together in 1999 to discuss the challenges surrounding CAPD service provision in South African (CAPD Taskforce business plan 2; 2001; Saleh et al., 2003; Fouche-Copley et al., 2016). In 2000, the CAPD Taskforce was formed to address these challenges (CAPD

Taskforce business plan 2; 2001; Saleh et al., 2003). It was noted that the use of materials containing sentences in an American accent, although pivotal in the diagnostic process, are not valid in the South African context as they have a high linguistic load. The taskforce recommended using testing material with a low linguistic load: material with monosyllabic words and numbers/digits instead of sentences in the interim – "Low linguistically loaded central auditory processing test protocol" (South African CAPD Taskforce, 2000). This protocol included the following behavioural tests: 2-pair DDT, frequency patterns or the pitch pattern sequence test, duration pattern test, psychoacoustic pattern discrimination test and masking level difference test. Refer to Appendix A for the full recommended protocol. Furthermore, they concluded that there was a need to develop more appropriate test material and normative data for the South African context (CAPD Taskforce business plan 2; 2001; Saleh et al., 2003).

Following these recommendations Saleh et al. (2003) and Campbell and Wilson (2003) conducted studies to evaluate the efficacy of the proposed "low linguistically loaded central auditory processing test protocol". The former study focused on South African English first and second language speakers aged 18–30 years, while the latter focused on English first language speaking children aged 8–12 years. The studies furthermore compared their results against the normative data by Bellis (2003), Bellis & Ferre (1999), Chermak and Musiek (1997) and Wilson & Strouse (1998) in the corresponding ages from American participants. The studies by Saleh et al. (2003) and Campbell & Wilson (2003) showed a poor performance by South African participants when compared to their American counterparts. This was particularly evident on the 2-pair DDT. These studies focused on assessment of binaural integration using the 2-pair DDT. Despite the fact that the 2-pair DDT was chosen for its low linguistic load, South African participants achieved the second lowest performance scores in this test when compared to their American counterparts than in any of the other tests. More striking is the finding that South African second language English speakers performed worse than South African English first language speakers, suggesting a linguistic bias. When Saleh et al. (2003) compared South African English first language speaking adults' results against the American normative data, they saw differences as large as 23.6% on the 2-pair DDT. This study proved two things; first, that the current tests, including the 2-pair DDT are not valid for use in the South African context, and second, that the American normative data are not appropriate for use in South Africa and its continued use in South African context can lead to false positives. The

authors recommended that the test stimuli should be used with caution in the younger age group as it yielded poor scores and could possibly be difficult for the client to complete. Both studies cautioned against using the American normative data provided by Bellis (1996, 2003) as they might not be appropriate for use among South African English speakers. The current study aims to adapt a CAPD test to better suit the needs of the South African context. As there are data suggesting that even the 2-pair DDT could have a linguistic bias, the study aims to adapt the 2-pair DDT by re-recording it in a South African English accent to better suit the South African context. The 2-pair DDT is easy to administer and provides invaluable information during CAPD assessment as it is sensitive to lesions in the brainstem, cortical and subcortical areas of the CANS as well as the corpus callosum (Shahmir et al., 2015; Selvaraj, 2018; Sona & Vanaja, 2018; Fattahi, et al., 2019).Furthermore, the study will develop preliminary normative data for use in South Africa until they are validated.

At the time of the writing of this thesis, the challenges faced by South African audiologists in the CAPD field persist. A research article written by Fouche-Copley, Govender & Khan (2016) found that the provision of CAPD services was low in South Africa. Similar to the finding of Bantwal, (2011), this was most evident in rural areas where the services are focused on overwhelming cases of competing health conditions that commonly cause hearing impairments leaving little to no resources for providing services in CAPD. Furthermore, South Africa still lacks context-specific tests and normative data. These challenges motivate the need for the current study. It is worth noting that the Fouche-Copley et al. (2016) article was written 14 years after the studies by Campbell & Wilson (2003) and Saleh et al. (2003). Fourteen years later and the challenges identified by the South African CAPD Taskforce still affected the field of CAPD in South Africa. The current study is necessary as it aims to address these long-standing challenges by developing a context-specific 2-pair DDT and generating preliminary normative data for the South African context.

2.7 Study purpose

This study aims to address the challenges discussed thus far by re-recording the 2-pair DDT to a South African English accent using a proposed developmental process. Following the latter, the study investigates if there is a statistically significant difference in the 2-pair DDT scores when the stimulus is presented in an American English accent versus a South

African English accent. Additionally, the study investigates if there is a statistically significant difference between the South African English first and second language speakers on the 2-pair DDT. The study aims to generate 2-pair DDT normative data for South African English-speaking adults. This study will generate data that can potentially give insight as to how tests can be developed or adapted to best suit the context and population for which the test is intended.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter focuses on the study aims. It further discusses and motivates for the research methodologies used in relation to the aims. The participants, sampling and data collection methods are examined fully, and rationales are given at each section particularly in how they help achieve the study aims. The ethical considerations are also discussed in relation to the study participants.

3.2 Aims

Aim: 1 To adapt the 2-pair DDT to be more appropriate for the South African context.

Aim 2: To determine the effect of a change in the accent of the 2-pair DDT from American English accent to South African English accent on dichotic digit test performance.

Aim 3: To generate preliminary normative data for both the American accent 2-pair DDT and the newly recorded South African 2-pair DDT from South African English-speaking adults.

3.3 Hypotheses to be tested

(i) Null Hypothesis (H0): The 2-pair DDT performance of South African adults will have no statistically significant difference when administering the test in an American English accent and a South African English accent.

(ii) Alternate Hypothesis: There will be a statistically significant difference between the 2-pair DDT performance of South African adults when the test is administered an American English accent and a South African English accent.

(iii) Null Hypothesis (H0): There will be no statistically significant difference between the 2-pair DDT scores of South African first language and second language English speakers on the SA accent 2-pair DDT.

(iv) Alternate Hypothesis: There will be a statistically significant difference between the 2-pair DDT performance South African first language and second language English speakers on the SA accent 2-pair DDT.

3.4 Study design

The researcher incorporated a developmental study design for the first aim. Developmental research is defined as an interactive cyclic process in which theoretical ideas of the researcher or ideas feed the development of products that may be tested and eventually lead to a product that may be used in practice (Richey, Klein & Nelson, 2004 & Ibrahim, 2016).

This design was deemed appropriate as it carefully outlined how to create an effective tool that may be used in practice (Richey et al., 2004 & Ibrahim, 2016). It does so in five stages, namely analysis, design, development, implementation and evaluation.

The analysis stage is defined as where the researcher reviews literature and performs a needs analysis to gain an insight into the problem statement and better understand the needs of the population. In the current study, the context is South Africa. The researcher noted that this stage corresponds with the study's background and literature review. As such, the study background and literature review are treated as a research method to generate findings for the analysis stage.

The design stage includes using the information obtained in the analysis stage to provide/devise a solution. The design specifications need to be researched and even modified if they are part of the solution. In this stage, potential stakeholders and/or experts are identified and consulted for input.

The developmental stage is seen as the authoring and production of the product. Where necessary, stakeholders apply their skills to help produce the desired tool. In this stage, the researcher created the proposed tool, using all the information and resources from the design stage to solve the needs or fill the knowledge gap identified in the analysis stage.

The implementation stage involves the application of the developed product to a target population (Sullivan, Ice & Niedermeyer, 2000; Ibrahim, 2016). Here the researcher administered the created tool to a sample of participants described in section 2.7 Participants.

The evaluation stage is where the researcher determines the value and importance of the applied product and measures its effectiveness. A formative evaluation was chosen for evaluation as it is considered fundamental to developmental design (Ibrahim, 2016). It helps to identify the deficiencies of a product and it involves the process of gathering information on adequacy and using that information as a basis for further development.

Formative evaluations are defined as informal and use observations, comments and reviews to determine the value and importance of a tool (Ibrahim, 2016). This stage has three different sections.

(i) **Design review:** consulting with experts identified in the design stage regarding the design guidelines and specification of the proposed tool.

(ii) **Participants' subjective feedback:** obtaining participants' comments, perceptions and experience of the developed test.

(iii) **Research assistant feedback:** research assistants comment on the usefulness and appropriateness of the developed tool.

The flowchart in Figure 1 illustrates a summary of the developmental design described by Ibrahim (2016) as applied in this study.

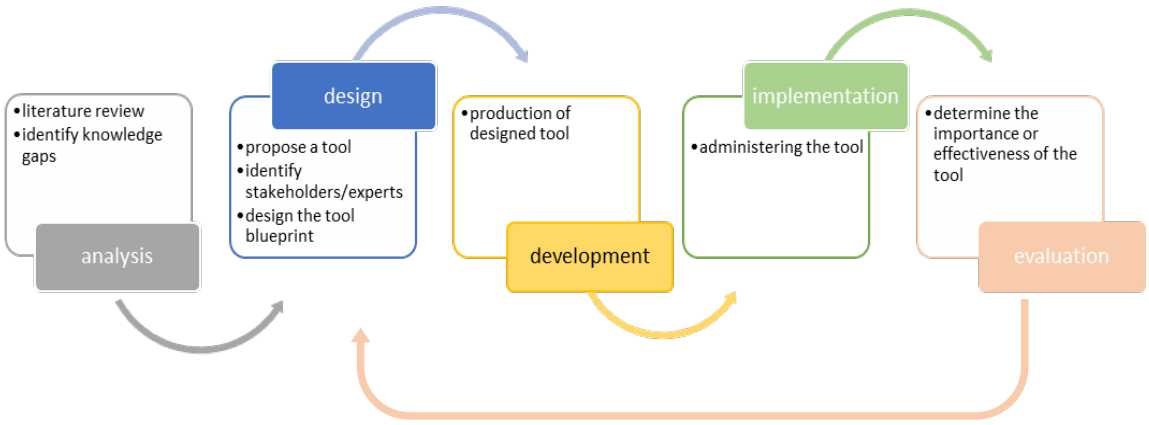

Figure 1: Developmental study design flowchart

To achieve Aim 2, the researcher used a cross-sectional comparative research design. A cross-sectional study is one that takes place at a single point in time. The cross-sectional aspect of this study design allowed for the observation of and measurements of 2-pair DDT performance of the current study's participants and the comparative aspect allowed for comparison with similar study findings (Trochim & Donnelly, 2001). As each participant was tested under two different conditions, they became their own control. In this study, the conditions were test performance when using test material in a South African accent and test performance when using the existing material in an American accent. Any change in test performance was attributed to the independent variable (Trochim & Donnelly, 2001). The researcher acknowledges that this design includes the application of a test to a target population/field testing, which is essentially the implementation stage of a developmental

study design. As such, the implementation stage is referenced in all areas concerning the administering of the developed tool.

A disadvantage of this study design is the potential rise of test-retest effect (Trochim & Donnelly, 2001. As the test required the same skill and followed the same procedure, it was possible for the participants to gain experience during the first test session and this would simulate improved performance in the results of the second test conditions. This was minimised by randomly assigning participants to be assessed either using the new South African accent 2-pair DDT or the American accent 2-pair DDT (Trochim & Donnelly, 2001). Another disadvantage is that it only measures observations at one moment in time. However, as Kimura's theory of dichotic listening has been widely accepted since 1967 and still applies to date the results of this study can potentially be true for an extended period of time.

3.5 Sampling

Non-probability sampling was used in this study. In this form of sampling, the odds of any participant being elected to be included in the sample cannot be calculated (Trochim & Donnelly, 2001; Etikan, Musa & Alkasim, 2016). Convenience sampling was used as it is easy, cheap and makes use of the participants that are easily available for the study (Trochim & Donnelly, 2001; Gelo, Braakmann, & Benetka, 2008; Etikan et al., 2016). Purposive sampling ensured that the researcher recruited the participants of interest, i.e. adult English speakers aged between 18 and 65. Snowballing was also employed. In this form of sampling, the researcher informed participants and students about the study and asked them to share the information with their peers and anyone meeting the inclusion criteria. A limitation to these forms of sampling is that it limits generalising the findings to the larger population of the Western Cape or South Africa.

The G-Power sample size calculator was used to determine the sample size required for this study. This is a widely used sample size calculator that can predict the minimum effective sample size needed in a study (Faul, Erdfelder, Lang, & Buchner, 2007). Using an alpha value of 0.05, an effect size $|p|$ of 0.3 and a power value of 0.80, the required sample size for this study was 84 participants for Aims 2 and 3.

3.6 Recruitment

Recruitment began as soon as ethical approval was granted (HREC FEF: 620/2018). See Appendix B for the ethics approval letter. As the study required the University of Cape Town, students and staff to participate, permission was asked and granted by the Executive Director of the Department of Students Affairs as well as the Director or Human Resources. See Appendix C and Appendix D for the approval letters to conduct the study of students and staff respectively.

Participants were recruited by means of the University of Cape Town online portal Vula, where notifications were sent out to the entire University of Cape Town body, both staff and students. Word of mouth was also employed to maximise the advertisement of the study. The researcher informed students about the study and asked them to share the information with their peers and anyone, meeting the inclusion criteria. This resulted in the study information being shared though social media such as WhatsApp and Twitter. Posters were also placed around the University of Cape Town campuses and residences to maximise recruitment. Refer to Appendix E for the recruitment letter and Appendix F for the study poster.

3.7 Participants

3.7.1 Inclusion criteria

Participants were only included in the study if they were South Africans. This was done as one of the study's aims is to collect preliminary normative data specific for use in South Africa. Participants had to be at least 18 years old as this age group has achieved neuromaturation, a factor that affects auditory processing. The age 18 was chosen as the University of Cape Town Children's Institute defines a child as someone under the age of 18 (Mahery & Proudlock, 2011). Furthermore 18 was chosen as a reference and comparison to the study by Saleh at al, (2003). This age group also forms the majority of the University of Cape Town body in close proximity to the Audiology research lab and thus easier and more convenient to recruit. As the original 2-pair DDT stimulus is in an American English accent and the study is investigating the influence of accent on DDT performance, the participants had to be English speakers. This way the researcher could accurately study the effect of accent as the independent variable and control or avoid language (not speaking English) as a confounding variable. To be included in the study,

participants had to have normal peripheral hearing and middle ear functioning so that DDT performance could not be affected by a reduced hearing sensitivity. Refer to Data collection procedures Part 1 for the criteria used to judge normal hearing.

3.7.2 Exclusion criteria

The following exclusion criteria was used:

- History of head trauma or ear surgery
- Abnormalities found during any part or assessment in the study. See Data Collection for a full detail of the parts of the study and the assessment done.
- Being above 65 years old to limit possibilities of presbycusis (Gates & Mills, 2005).
- Sign of dementia or a diagnosis of dementia.
- Showing or reporting signs of processing difficulties in the case history.
- Use of any ototoxic medication (eg, TB medication, hypertension, heart failure medication such as, furosemide/Lasix bumetanide or cancer medication such as cyclophosphamide, cisplatin, and bleomycin. etc.).
- Exposure to loud noises 24 hours prior to the assessment.

These conditions are known to affect peripheral hearing which would affect the use of the data for normative purposes and could affect auditory processing (ASHA, 2005).

3.7.3 Participant description

A total of 88 individuals, (18–62 years) from the University of Cape Town and the surrounding areas (Rondebosch, Mowbray and Observatory) were recruited for the study. The study location was chosen to maximise availability. The age range was chosen as this group has achieved neuromaturation, which is a factor that affects CAPD tests (ASHA, 2005). It is also wide enough to provide data for normative purposes (Trochim & Donnelly, 2001). Furthermore, the University of Cape Town uses English as its primary mode of instruction. This meant that participants who responded met the inclusion criteria of being a first or second language English speaker.

Four participants failed to meet the inclusion criteria and thus all the information pertaining to them has been excluded from the study. Two participants had type A_D tympanograms in the right ear while the last participants had bilateral type A_D tympanograms, which

indicated a possible ossicular discontinuity. All three of the participants had normal hearing. Their results were explained to them including a possible site of lesions. They were all referred to healthcare providers near to them for further assessment and management. At the end of the study the only results that were included in the data analyses were those of the 84 participants who presented with normal hearing and reported no symptoms of CAPD or any excluding factor. This number meets the minimum effective sample size as calculated using the G-Sample size calculator.

Of the 84 participants included in the study, two identified as Asian, 29 participants identified as Black, 20 participants identified as Coloured, three as Indian and 30 participants identified as White. The average age of the participants was 23 years, the mode was 19 years and the median age was 21 years. The age range was 44 years, with 18 years as the minimum age and 62 the maximum age. The sex of the participants comprised 20 males and 64 females. For the purpose of this study, sex was defined as biological characteristics such as genitalia and genetic differences in the twenty-third chromosome pair that define humans as male or female (World Health Organization/WHO, 2019). Forty-five participants reported speaking English as their first language and 40 reported that English was their second language. Table 1 shows the first languages of all the participants included in the study.

Table 1: Participants' first languages

Participants' first language	Frequency
Afrikaans	10
English	45
IsiXhosa	9
IsiZulu	2
Khelobedu	1
Mandarin	1
Ndebele	1
Sepedi	6
Sesotho	1
Setswana	4
Swati	1
Vhenda	1
XiTsonga	2

3.8 Data collection

Prior to collecting data, ethical clearance was obtained from the Faculty of Health Sciences Human Rights Ethics Committee (HREC REF: 620/2028). See Appendix B for the ethical clearance letter.

Aim 1: To adapt the 2-pair DDT to be more appropriate for the South African context.

The development of a contextually appropriate 2-pair DDT for the South African context adapted a developmental study design originally used in instructional technology. As stated in the study design section, the developmental design includes five stages to create a tool: analysis, design, development, implementation and evaluation. When applying these steps in the present study, various research methods were used. These methods and their application in the study are summarised in Table 2:

Table 2: Research methods used during the developmental process of the study

Steps in development process	Research method	Application in study
Analysis	Literature review	To better understand the research problem and needs within the context of South Africa.
Design	Consultation with experts	Identify experts. Devise a possible solution to the problem. Create tool specifications.
Development	Consultation with experts Production of test	Collaboration with experts. Production of the tool with aid of the experts.
Implementation	Aim 2: Field testing Observation	Administering the developed tool to participants and documenting their test performance. The researcher then observed participants as they took/used the new tool and documented any reaction to the test whether verbal or non-verbal.
Evaluation	Short structured interview	Experts in the field of electrical engineering commented on the feasibility of the designed tool and its production. Participants commented on their perception of the new test and control. The research assistant gave feedback on the designed tool.

Analysis: To better understand the research problem and needs within the context of South Africa.

As noted in the study design section, the study background and literature review are treated as a research method, i.e. they serve as method for obtaining the findings of the analysis stage. In summary, the researcher applied this stage by researching extensively by reading textbooks and journal articles to identify the current state of CAPD in terms of assessment, service provision and the current research within the context of South Africa, particularly to identify the knowledge gaps and needs of the South African population within the field of CAPD. See, Background and literature review for the main findings of the literature review.

Design: Devise a possible solution to the problem

This stage follows up on the findings of the analysis stage and did not need any specialised equipment. The researcher proposed to adapt the 2-pair DDT to better suit the needs of the South African population by re-recording it in a South African English accent. The reason for choosing the 2-pair DDT is discussed comprehensively in the Validity of CAPD assessment tests in South Africa section of Chapter 1. The following steps were part of the design stage:

(i) The researcher identified the guidelines and specification of the 2-pair DDT.

(ii) The researcher consulted with Prof. Richard Wilson, a senior researcher, to advise on how to re-record as well as any considerations that had to be taken into account. He also advised that no permission is needed to modify the test as it uses everyday numbers.

(iii) The researcher consulted an electrical engineer, who was presented with the specifications of the 2-pair DDT, the modifications suggested by the researcher as well as a recording of the 2-pair DDT. He was then asked to advise on the effectiveness of the design and the feasibility of the proposed solution. This step is referred to in the evaluation stage as it is a design review – a form of informal evaluation. The recommendations are included in the study results.

(iv) The researcher negotiated with the UCT radio station staff to help with the recording of the tests and to provide a speaker for recording.

Development: Production of the 2-pair DDT with aid from the stakeholders.

Procedure

This stage used all the information and resources from the analysis and design stages. This is where the actual 2-pair DDT was re-recorded in a South African accent. The researcher met with UCT Radio's station manager and technical manager. The technical manager was an electrical engineer student who upon looking at the specifications of the 2-pair DDT recommended the following to ensure that the quality of the 2-pair DDT met the Department of Veteran Affairs/DVA (1998) standards:

Tools and equipment

1 Rode NT1-A Microphone.

2 Soundproof booth: to control for and reduce ambient and acoustic noise while recording test material.

3 Two-pair DDT material list containing the original number sequences used.

The radio technician was briefed regarding the senior researchers' recommendations and he agreed with the recommendations. Furthermore, he and the researcher prioritised selecting a speaker for the recording of the test. As the DVA (1998) 2-pair DDT specifications indicate that the speaker has to be male, the selection was narrowed down to male radio presenters to keep consistency between the resonant frequencies of the original recording and the current study recording and to avoid this being a confounder. Furthermore, a white English accent speaker was chosen as it carries the least localised transformations to consonants and has the highest recognition rate among South African English speakers (Kamper, 2012).

The technical manager liaised with the speaker and they picked a day where they both were available to record the test. After the date had been chosen, they communicated with the radio station's schedule manager to book the recording station. All tools and equipment were available and calibrated on the date of recording.

The technical manager's major role was to ensure that the quality of the 2-pair DDT met international standards described by the DVA. For the record format, as the original is a CD, the recording is in audio CD quality (44100Hz, 16-bit pulse-code modulation .wav) uncompressed, mono). Five recordings were done, and the clearest recording was selected.

With aid from the technical manager, the left and right channels were recorded separately and then combined post-processing. Once everything had been recorded and edited, it was exported in stereo, 441000Hz, 16-bit PCM uncompressed audio. The timing between digits and sets was exaggerated during recording and then cut down to approximate the required time as specified by the DVA (1998).

Implementation: In this stage the researcher administered the test (field tested) to the study's sample. The collection of the data from administering the SA accent 2-pair DDT was part of the study's Aim 2. Thus, the procedure is detailed in that section. See Data collection, procedures in Aim 2, part 2, for a detailed description of this stage.

Evaluation: To determine the values and importance of the 2-pair DDT.

A formative evaluation was done with the electrical engineer, research assistants and participants. This was done in three distinct stages:

1 **Design review:** The original 2-pair DDT was given to an electrical engineer along with the test guidelines and specifications to determine if the test could be replicated at the same quality level and furthermore recommend where it could be done and the equipment necessary.

2 **Participant subjective feedback:** Data collection for Aim 2 included a session where the participants were asked to comment on the 2-pair DDT. A full description of this process is found under the procedure for Aim 2.

3 **Research assistant feedback:** After the study had concluded, the researcher conducted a short interview with the research assistants during which they were asked to comment on the newly developed SA 2-pair DDT. They were asked an open-ended question: "What are your thoughts and comments on the adapted 2-pair DDT?" Three main short answer questions were suggested when guidance was needed: 1) How is the quality of the tool? 2) Is the tool useful or appropriate? and 3) Can the tool be improved and if yes, how?

Aim 2: To determine whether there is a statistically significant difference between the 2-pair DDT scores obtained with the original American 2-pair DDT material versus the newly recorded South African 2-pair DDT material.

Tools and equipment

1 Welch Allyn video otoscope (Digital MacroView™ Otoscope): A specialised torch that assesses the outer ear and tympanic membrane and projects it on a computer screen.

2 Lenovo Yoga 300 series Laptop: An 11.6' HD laptop running Windows 10 Home for connecting and using the video otoscope.

3 GSI (Grandson-Stadler, United States of America) Tympstar V2: a 226 Hz probe tone diagnostic middle ear analyser. Additionally, it assesses the stapedius reflex.

4 GSI 61 (Grandson-Stadler, United States of America): a two-channel diagnostic audiometer, with circumaural headsets, to assess air conduction and speech recognition thresholds (SRT) and a bone vibrator to assess for bone conduction thresholds.

5 Proline partner computer with intel dual core processor running Windows XP: for operating the Madsin Conera and DVD player during assessment for AP.

6 Madsen Conera: An exterior clinical audiometer connected to circumaural headsets, that will be used during the assessment of AP.

7 Sony DVD player DVP-NS51P: a DVD player to present the test stimuli recordings.

8 Tonal and Speech Materials for Auditory Perceptual Assessment Disc 2.0.: A compact audio disc containing high-quality auditory materials for use in assessing auditory perceptual (central) abilities.

9 Disc containing new 2-pair DDT list: a compact disc containing the newly recorded 2-pair DDT number list in a South African accent.

10 Record sheets: to document scores. Appendix G for the study record sheet.

According to UCT's Department of Health and Rehabilitation technician all audiological equipment is calibrated yearly between the January and March of 2018 and 2019, the years of the study's data collection.

At the start of each day of data collection, a biological test was performed to assess the equipment functioning. The audiometer was set at 1000 Hz, 30 dB HL and a tone was presented. The stimulus presentation button was then released to check if the sound ceased. The tone was then increased and decreased to check if the corresponding effect was heard through the headsets. Frequency would then be switched to 2000 Hz and it was checked if there was a hum or tone despite not presenting the tone. The tone would be presented,

increased and decreased to assess if the controls were working properly for all frequencies. It was also checked if the tones were coming through the right sides of the headsets. All equipment was thoroughly cleaned before and after assessing each participant using alcohol swabs and Dismed D-germ Hand Rub was used as an infection control sanitiser. This was done specifically on each speculum, tympanometer probe and the headsets used in the GSI 61 and Madson Conera.

3.9 Procedure

Pilot study:

Prior to large scale data collection, a pilot study was conducted. Ten participants formed part of the piloting. The piloting was used to determine the appropriateness of the study setting, time allocated for data collection, recruitment strategies, administration and resource availability. The aforementioned were found to be appropriate.

On the day the participant arrived at Audiology Research Laboratory, **E48 Room 12**, **Old Main Building**, Groote Schuur Hospital, the researcher issued an information sheet (see Appendix H for the study's information sheet**)** and consent form (See Appendix I for the study's consent form**)** containing all the details pertaining to the research study. The researcher was present to answer any questions they had. Upon signing the consent form, the participant was issued a number to represent him or her. The procedure was broken into two distinct parts.

Part 1 was to determine if the participants met the inclusion criteria. Only if this was met could the participants move to Part 2. See the inclusion criteria for more details. Part 2 was where the 2-pair DDT was administered and scored when presented in a South African accent and an American accent.

Part 1

1 Case history

The Audiology Research Laboratory was organised such that the participant could sit at 90 degrees to the researcher as advised by Northouse & Northouse (1998). This created a comfortable personal space for the participant and allowed the researcher to engage fully with the participant, who would then be asked to provide information about age, sex, first language and second language. Once that had been established, the participant was asked

questions about hearing and history of hearing loss and ear diseases. See Appendix J for the case history taking guide. It is important to note that the questions served as a guide; the researcher and research assistants used their clinical expertise to conduct a thorough and comprehensive case history. Clear, simple verbal open-ended and closed-ended questions were asked to gather information. Any symptoms reported were noted at the back of the record sheet. See Appendix G for a detailed study record sheet.

2 Otoscopy

The researcher first inspected the participant's pinna, mastoid bone and the level of the ears for any abnormalities. The researcher then proceeded to use a video otoscope to look into the participant's ears. It was explained in a clear, simple, verbal manner that the test is done to make sure that the ears are suitable for hearing tests; i.e. that there is no ear wax impaction, foreign body or signs of infections in the ear canal and to see if there are any abnormalities of the ear drum. These factors are known to affect hearing sensitivity (ASHA, 2005). The results were then recorded on the record sheet.

3 Tympanometry

This test was done to assess the functioning of the middle ear. It was explained to the participant that the test involves placing a soft probe in the ear and introducing some pressure. It was emphasised that the test is not harmful but that the participant should inform the researcher should any pain be experienced. The participants were encouraged not to speak, chew or swallow during the testing. The participant's ear canal volume, middle ear pressure and tympanic membrane compliance were recorded on the record sheet. Normal tympanometry results were judged as a compliance between 0.2–2.0 cm3, an ear canal volume of 0.2–2.0 cm3 and a middle ear pressure of -150–100 daPa (Narayanan, 2017).

4 Acoustic reflex testing

This test was done to assess the contraction of the stapedius muscle (Narayanan, 2017). The participants were informed that two soft probes would be placed in their ears and that they would hear a series of sounds. The testing was done for both ipsilateral and contralateral stimulation. The results were recorded on the study record sheet. The criterion for normal reflexes was a repeatable wave with an amplitude of 0.02 mm between 70–100 dB HL (Narayanan, 2017; Saxena, Allan &Allen, 2017). Furthermore, the reflex had to

show an increase in amplitude when the intensity of the stimulus was increased, as well a decrease in amplitude when the stimulus level was decreased.

5 Pure-tone audiometry test

The participants were then required to undergo a hearing test by listening to a series of tones (frequencies 250 Hz-8000Hz) played through circumaural headsets in an audiological booth to assess their hearing status and establish if they had normal hearing. The modified Hughson-Westlake procedure was used to assess hearing sensitivity. This is the most widely used method of measuring pure-tone thresholds (Schlauch & Nelson, 2014). The participants were given an instruction to press a button whenever they heard a sound, even if the sound was very soft. The results were recorded on the study record sheet. Normal hearing was judged as a PTA of 15 dBHL or less (Schlauch & Nelson, 2014).

6 Speech recognition testing

Speech recognition threshold testing was done to establish the reliability of the pure-tone results. The PTA and SRT values had to be within 10 dB HL to be judged as good reliability (McArdle & Hnath-Chisolm, 2014). While in the booth, circumaural headsets were placed over the ears. The participants were then informed that they would hear a list of words and that they needed to repeat back the word they heard. It was pointed out that the words would get softer as the test continued. They were further instructed that if they were not sure what they heard, they could guess. Live voice spondaic words list CID W-1, (closed set), which are the most widely used, were presented to the participants (McArdle & Hnath-Chisolm, 2014). The results were recorded on the study record sheet.

7 Word Identification testing:

This test was done to assess for the possibility of retro-cochlear pathologies. A live voice CIDW-22 wordlist was used during testing as the recorded CIDW-22 is in an American accent which is not valid for use in South Africa. The CIDW-22 wordlist is a list of phonetically balanced words that are widely used in word identification testing (McArdle & Hnath-Chisolm, 2014). The results were recorded on the study record sheet.

8 Feedback session:

The participants' results were then explained in a clear manner. Any abnormalities detected were explained to the participants and appropriate referrals were made. Three participants

were referred for further evaluation and possible management. One participant was referred to the University of Cape Town diagnostic audiology clinic and the other two opted to seek care from health institutions nearest to where they live. All participants whose results indicated normal hearing proceeded to the next part of the study.

Part 1 was done with help of two research assistants. Both research assistants hold a BSc Audiology qualification from the University of Cape Town. They were issued with a study outline that included the study's detailed procedure, including the instructions to give to the participants. This was to ensure uniformity in the data collection and capturing. Prior to data collection, they both had a meeting with the main researcher to discuss the study set up, their involvement, the procedures, administration duties, infection control and referral pathways. Furthermore, if they had any queries during data collection, they were encouraged to consult the researcher who was present at all times.

Part 2:

1 The participants were randomly allocated to one of two groups; one where assessment began with the newly recorded South African accent 2-pair DDT followed by original American accent 2-pair DDT or vice-versa. They were asked to pick a note from a hat marked either 1 or 2. This indicated the order in which the tests would be administered. The participants were not informed which test condition they would be starting with or that the test sessions differed in the accent of the test stimuli. A 5-minute break was allowed between the two tests to allow for a short rest and to limit test-retest effects. Administering the South African accent 2-pair DDT corresponds to the implementation stage of developmental design as described in study design section of the document.

2 Dichotic digits testing: The dichotic digit test contained 25 2-pair dichotic digit stimuli that included the numbers 1 till 10 excluding the number 7. The interval between the stimulus was 4 seconds. The numbers were presented simultaneously to the ears at 50 dB SL in relation to their threshold. The participants were informed that they were going to hear a list of number in their ears. They were asked to report the numbers back to the researcher irrespective of the order. All results were recorded on the record sheet. The first five stimuli were used as practice, while the remaining 20 stimuli (40 numbers per ear) were recorded with each number weighting 2.5%.

3 As part of the study's formative evaluation stage, the participants were asked to provide subjective feedback of the 2-pair DDT at the end of the data collection session. The participants were asked to comment on what they thought about the dichotic digits test for both study conditions. Any comments about the test itself or the perceived difference between the two tests were manually recorded at the bottom of the study record sheet. The responses were then collated on a Microsoft Word document.

4 After these assessments, the participants were given feedback on their test results. If the results were not within the Bellis (2003) normative data range, the applicability of the norm and purpose of the study were explained. The participants were then asked if they could be referred to the 4th year Audiology CAPD clinic for further assessment and management.

The full testing took between 45 and 60 minutes.

Aim 3: To collect preliminary normative data for both the American accent 2-pair DDT and the newly recorded South African accent 2-pair DDT from South African English-speaking adults.

The data collected in Aim 2 was used to achieve Aim 3.

The American accent and South African accent dichotic digit test scores were collected and loaded from the record sheets onto a Microsoft Excel data spreadsheet. After data collection was complete, the data was then exported from the spreadsheet to the IBM SPSS version 25 software where it was analysed. Both the American accent 2-pair DDT and the South African accent 2-pair DDT scores were analysed to show the means and the standard deviations around the means. As it is imperative for clinical significance and for comparison with former studies on dichotic listening, two standard deviations below the mean calculations were made (Saleh et al., 2003).

3.10 Data analysis

Prior to submitting the proposal and analysing data a statistician from the UCT Clinical Research centre was consulted to check the proposed analyses and give input. The statistician agreed with the proposed analyses and had no additional information to add.

The following analyses were done to achieve Aim 1:

Analysis: As mentioned in the study design and data collection, this stage is covered in the study's background and literature review. Data analysis does not apply to this section of the developmental design. The purpose of this step of the process was to inform the researcher about the current state of CAPD in terms of assessment, service provision and the current research within the context South Africa particularly the knowledge gaps and needs of the South African population within the field of CAPD.

Design: Data analysis does not apply to this stage of the developmental process.

Develop: The developmental process also has no data to analyse. The aim here was to re-record the test materials in a South African English accent, the endpoint of which is presented in the result section.

Implement: This stage included administering the test to a group of 84 participants. Analysis of test performance was based on the test criteria described in the Procedure section.

Evaluate:

1 **Design review:** the feedback obtained from the electrical engineer was noted down on a notebook and later reported in the results chapter. No analysis was required for this review.

2 **Participant's subjective feedback:** As part of the formative evaluation for Aim 1, the participants were asked to provide subjective feedback of the two versions of the 2-pair DDT at the end of the data collection session. A content analysis was used to analyse the participants' responses. Content analysis refers to a research method used to identify patterns in recorded communications. This form of analysis is important as it allows the researcher to find correlations and patterns in the feedback from the participants. The advantages of using this analysis are that it can be done at any place and time and it produces highly reliable and replicable results. The disadvantages of content analysis are that it is time consuming, reductive in that focusing only on certain phrases can lead to a disregard of the context and nuance of the data and the analysis involves some level of subjectivity. However, the current study did not have a large amount of qualitative data which minimised the time it took to analyse the data.

   The analysis was done by first selecting the data to be analysed. As the data set was small, it was all included in the analysis. Secondly, the researcher focused on analysing

the units of meaning in the data: words, phrases or descriptions the participants used for the two DDT recordings. Because a comparison was made between the American accent 2-pair DDT and the South African accent 2-pair DDT, the researcher focused on writing down each instance where they were described. In the end the researcher was left with a table including common descriptors of the American accent 2-pair DDT and the South African 2-pair DDT. The researcher then finally made an interpretation of all the descriptors to provide the participants main experience of the 2-pair DDT.

3 **Research assistant feedback:** the feedback obtained from the research assistants was summarised based on the key areas of critique and reported in the results section. No analysis was required for this review.

Aim 2: To determine the effect of a change in the accent of the 2-pair DDT material (from American English to South African English) on the 2-pair DDT scores of South African English-speaking adults.

The collected raw data on the record sheets were loaded on to a Microsoft Excel sheet using a Lenovo Yoga 300 series laptop (Windows 10 Home) with IBM SPSS version 25 software installed. This program was chosen as it allowed analysis of the data using both descriptive and inferential statistics. Descriptive statistics summarised the data and showed any patterns it assumed (Tredoux & Durrheim, 2013). Measures of central tendencies, i.e. mean, mode and median, aided in providing a vivid picture as to where most of the data lay (Tredoux & Durrheim, 2013). Measures of central dispersion (variance, standard deviation, and interquartile range) on the other hand helped minimise the disadvantage of the measures of central tendency as it they showed how the data were spread around the mean (Tredoux & Durrheim, 2013). Furthermore, combining these two helped achieve Aim 2: generating means and standard deviations for generating preliminary normative data (Tredoux & Durrheim, 2013).

The Shapiro Wilk test was used to assess if the data assumed a normal distribution (Trochim & Donnelly, 2001). This was done as it has implications on whether the data would be analysed using parametric or non-parametric statistics. As the data were not normally distributed, a Wilcoxon signed ranked test (non-parametric statistics) was then used to compare the sample means of the data. Specifically, this was done to calculate firstly, if there was a statistically significant difference between the 2-pair DDT scores of South African adults when the test stimulus was switched from an American English accent

to a South African English accent and secondly, if there was a statistically significant difference between the South African accent 2-pair DDT scores of South African English first language speakers and South African English second language speakers. This test was suited for this study as it calculates the differences of the means in the two test conditions when data are not normally distributed and shows whether that difference is statistically significant (Tredoux & Durrheim, 2013).

Aim 3: To collect preliminary normative data for both the American accent 2-pair DDT and the newly recorded South African accent 2-pair DDT from South African English-speaking adults.

No additional analyses were done to achieve this aim. The results obtained in achieving Aim 2 were tabulated to show the means and standard deviations (both American accent and South African accent 2-pair DDT scores) and serve as preliminary normative data for use in South Africa until they are validated.

3.11 Ethical considerations

Prior to collecting data, ethical clearance was obtained from the Faculty of Health Sciences Human Rights Ethics Committee (HREC REF: 620/2028). This study conformed to the ethical principles that have been outlined in the declaration of Helsinki as they are essential in Healthcare practice (World Medical Association, 2013; Naudé & Bornman, 2014).

Autonomy- the participant's ability to make sound and informed decisions regarding their participation in the study (World Medical Association, 2013; Naudé & Bornman, 2014). All of the participants were given an information sheet detailing all the information regarding the study and asked to give consent prior to data collection (See Appendix H for the study's information sheet and Appendix I for the informed consent)**.** All the benefits and risks of the study were outlined and stated by the researcher prior to data collection. Furthermore, they were made aware, explicitly, that their participation in the study was 100% voluntary and that they may withdraw at any point without penalties.

3.11.1 Beneficence

The researcher of this study attempted to maximise the benefits of the research while minimising any harm to the participant. The participants received a free hearing evaluation and appropriate referrals where their results indicated any possible abnormalities.

Furthermore, there were two lucky draws with a chance to win a R500 Takealot vouchers at the end of the study.

3.11.2 Non-maleficence

This principle requires the researcher to ensure that no harm will fall on the research participant as a direct or indirect consequence of the research. Procedures in this study were not harmful or invasive. In cases of incidental diagnosis, emotional and information counselling were provided as well as a referral to where the potential participant could go for further assessment and management.

3.11.3 Justice

Justice requires that the researchers treat all research participants with fairness and equity during the stages of the research study (Wassenaar, 2006). It is also the ethical obligation to treat each participant morally correctly and to give each participant what is due to them (Goyal, 2013). Anyone who met the inclusion criteria was given the opportunity to volunteer for participation in this study. Furthermore, all participants were provided with an opportunity to ask questions and be given answers in a courteous manner. These rights were applied to any participant who chose to withdraw from the study and were applied to those who were referred for further evaluations and possible management (Goyal, 2013; Muller & Kouyate, 2005).

As the researcher is a staff member, it was made explicitly clear to all students who expressed interest to participate in the study that they were under no obligation to participate, and that their participation or withdrawal from the study would not positively or negatively impact their studies. Furthermore, data collection was done at a time that suited the participants, which did not clash with their studies or any other commitments that they may have had.

3.11.4 Confidentiality

Confidentiality is an agreement between the researcher and participant to uphold the participant's privacy and not to share the participant's information without the participant's permission (Van der Val, 2005). No personal identifying information was collected in the study. Participants were assigned a number at the beginning of the study to represent them and hide their identity. The data collected were stored in a locked cabinet situated in the

researcher's office. The digital data does not have any information that could identify the participant and it is stored in an encrypted compact disc that will be stored with the hard data. The data is also backed up on Dropbox, a cloud drive used for storing information. Only the researcher has access to this information. This will be kept until the data are published.

CHAPTER 4 RESULTS

4.1 Introduction

This chapter presents the findings of the current study. The findings of aim 1 will be presented in relation to the five main stages of the development process: analyses, design, development, implementation and evaluation. Furthermore, where appropriate in other aims, the stages of the developmental process will be referenced.

Aim 1: To adapt the 2-pair DDT to be more appropriate for the South African context.

Analyses:

As mentioned in the study design and data collection, this stage is covered in the study's background and literature review. In summary, the analysis stage revealed the following:

(i) The majority of tests and normative data commonly used for CAPD assessment are not appropriate for use in South Africa. Even the low linguistically loaded central auditory processing test protocol that was proposed as a solution for the latter is not appropriate. More striking is that research shows that even the 2-pair DDT, despite fundamentally being a test with minimum linguistic load, carried a linguistic bias that negatively affected the South African population and was thus not valid or appropriate for use in clinical settings (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; Fouche-Copley et al., 2016).

(ii) Invalid CAPD tests and normative data could lead to false positive test results.

(iii) There is a need to adapt CAPD tests to suit the needs of the South African population and subsequently generate context specific normative data (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; Fouche-Copley et al., 2016).

(iv) The researcher found no studies aimed at adapting CAPD tests or generating normative data for use in South Africa.

(v) Furthermore, the researcher did not come across research aimed at describing the developmental process for adapting CAPD test to suit the needs of a specific context.

Design:

The outcome of this stage was the recording of the adapted 2-pair DTT in a South African accent with the same specifications of the original DVA recording. See Appendix K for the guidelines and specification of the 2-pair DDT.

Development:

The electrical engineer assured the researcher that the 2-pair DDT could be replicated as per the guidelines and specifications described by the DVA (1998) by using equipment found in a radio station. It was further recommended that the radio station staff could facilitate the recording process. Table 3 shows the specifications achieved when the 2-pair DDT was recorded to a South African English accent.

Table 3: South African accent dichotic digit test specifications

	Left Ch	Right Ch	Time South African accent	Stimulus duration	Interval size
1	4,3	1,6	0:01	0:01:88	0:04:14
2	3,1	9,10	0:06	0:01:88	0:04:14
3	9,6	1,5	0:12	0:02:07	0:03:95
4	2,10	6,8	0:18	0:01:69	0:03:95
5	4,8	6,9	0:24	0:01:88	0:04:14
6	9,1	10,2	0:30	0:01:88	0:04:14
7	2,4	9,10	0:35	0:01:88	0:04:14
8	1,9	8,6	0:41	0:01:88	0:04:14
9	2,4	3,9	0:47	0:01:88	0:04:14
10	1,4	10,5	0:53	0:02:07	0:04:14
11	2,5	1,3	0:59	0:01:69	0:04:14
12	4,5	2,6	1:05	0:01:88	0:03:95
13	3,10	5,6	1:11	0:01:69	0:03:95
14	4,1	9,5	1:17	0:01:69	0:03:95
15	4,5	3,8	1:23	0:01:69	0:04:14
16	9,5	4,1	1:29	0:01:88	0:04:14
17	4,5	10,2	1:35	0:01:69	0:04:14
18	9,8	3,4	1:41	0:01:88	0:03:95
19	9,10	8,5	1:47	0:02:07	0:04:14
20	8,6	4,1	1:53	0:01:88	0:03:95
21	6,8	10,2	1:59	0:02:07	0:04:14

	Left Ch	Right Ch	Time South African accent	Stimulus duration	Interval size
22	9,1	2,8	2:06	0:01:88	0:04:14
23	6,9	3,1	2:12	0:02:07	0:04:14
24	1,2	3,9	2:18	0:01:88	0:03:95
25	5,3	2,1	2:24	0:01:50	

Key: Left Ch = Left Channel
Right Ch = Right Channel
Time South African Accent = Starting of the stimulus set in the South African accent 2-pair DDT
Stimulus duration = duration of the stimulus in seconds set presented in each ear

The test specifications listed in Table 3 meets all the specification of the DVA (1998). See Appendix K for the DVA specifications.

Implementation:

The adapted 2-pair DDT was conducted on 84 participants. The findings related to test performance and general outcomes of the implementation are reported in the results of Aim 2 of the study.

Evaluation:

As stated in the methodology section, this stage was an informal evaluation with three distinct steps that will be reported as such. The results for the design and research assistant feedback will be reported in its initial format since the data did not require analysis.

(i) **Design review:** An electrical engineer concluded that the test could be replicated with radio station recording equipment. Senior researchers in the field of CAPD recommended that the study use a radio presenter for test recording to maintain a good voice quality

(ii) **Participant review:** The participants were asked to comment on 2-pair DDT for both sessions. All the participants' responses were noted verbatim at the bottom of the record sheet.

As stated in the data analysis, this section was analysed using content analysis. The participants used the following words to describe the 2-pair DDT.

Table 4: Dichotic digit common descriptors

American accent 2-pair DDT	SA accent 2-pair DDT
Robotic	Familiar voice
Monotonous	Typical voice
Automated	Realistic
Recording	Human or how people speak
Not human (siri)	Having intonation
Computerised	Stress inducing
Monotone	Anxiety inducing
Stress inducing	Nerve wracking
Anxiety inducing	Easier
Nerve wracking	
Difficult	

The descriptors used by the participants are centred around the type of voice in two respective 2-pair DDT recordings. On the one hand, the American accent 2-pair DDT was described mainly as being robotic, foreign or as if it was not a human recording. In its current state, the 2-pair DDT recording is in an accent the participants do not hear in their day-to-day communications. Another distinct word used to describe the test was that it was difficult. In contrast, participants reported the SA accent 2-pair DDT to be easier. As seen in Table 4, some of the words used to describe it are *typical voice* and *realistic*. From this, the main theme of the participants' responses is that the stimulus recording of the American 2-pair DDT is not the same accent they hear and use to communicate in their daily living.

It is, however, worth noting that both groups found the test to be stressful. The researcher noted three instances during the feedback sessions where the participants expressed irritation towards the American accent 2-pair DDT with one participant explaining "They (test and normative data) are for America, I am South African and Afrikaans".

(iii) **Research assistant feedback:** The research assistants provided a review of the newly adapted 2-pair DDT focused on two main areas;

- Purpose of the test: in terms of how the stimulus is presented, dichotically, and thus it can be assumed to be sensitive to the areas of the CANS as reported in

literature. The defining superiority of the tool is that it is in a South African accent. Anyone assessed with this new test would have to focus less on adapting to the accent and more on trying to perform in the test to the best of their abilities.

- **Test length:** The new test appears to be 9 seconds longer than the original test. While this is most likely negligible, this may allow for a split second more time to process the stimuli being provided. The test would benefit from being trimmed down to match the length of the original tool in order to eliminate any possible aspects of contention.

Aim 2: To determine the effect of a change in the accent of the 2-pair DDT material (from American English to South African English) on the 2-pair DDT test scores of South African English-speaking adults.

Having the newly adapted South African accent 2-pair DDT, the researcher then implemented it to assess South African adults (18–62 years). Furthermore, the researcher assessed the same group with the existing American accent 2-pair DDT and compared the results. Table 5 summarises the results found:

Table 5: South African accent 2-pair DDT scores versus American accent 2-pair DDT scores

	South African accent 2-pair DDT		**American accent 2-pair DDT**	
	Right ear	**Left ear**	**Right Ear**	**Left ear**
Mean	97.65	97.53	94.07	94.91
Standard deviation	3.11	3.11	5.39	5.64
Range (minimum-maximum)	10 (90-100)	10 (90-100)	25 (75-100)	25 (75-100)
Median	100	97.81	95	97
Skewness	-1.07	0.83	-1.13	-1.12
Kurtosis	1.28	0.656	1.73	0.87
Shapiro-Wilk test	0	0	0	0

When the 2-pair DDT is in an American accent, the skewness and kurtosis of the data is -1.13 and 1.73 in the right ear and -1.12 and 0.87 in the left ear. Bilaterally, this indicates that the data is skewed to the left, meaning that few participants achieved low DDT scores or conversely most participants achieved high DDT scores. The value of the kurtosis shows

that the tails are not heavy, i.e. there are few outliers which further strengthens the finding of the skewness. A Shapiro-Wilk test was done to test whether data were normally distributed and a score of 0 was found for both ears. A score of 0 indicates that the data were not normally distributed. This corresponded to the values found when calculating the skewness. The mean test score of South African adults tested with American accent 2-pair DDT was 94.07% (SD=5.39%) in the right ear and 94.91% (SD=5.64%) in the left ear. While the mean values are high, there was a big variation, indicated by the standard deviations on the scores. This would suggest there is a big variation between the 2-pair DDT scores of South African adults when assessed using the American accent test.

When using the newly developed South African accent 2-pair DDT, the skewness and kurtosis of the data was -1.07 and 1.28 in the right ear and -0.83 and 0.66 in the left ear. Bilaterally, this indicates that the data is skewed to the left, but the kurtosis shows that the tails are not heavy, i.e. there are few outliers. A Shapiro-Wilk test was done and a score of 0 was found for both ears. This corresponds to the values found when calculating the skewness. A mean value of 97.65 percent (SD=3.11) was found in the right ear and 97.53 percent (SD=3.11) in the left ear. The mean was high, and the standard deviation was low, indicating low variation between the test scores of South Africans on the South African accent 2-pair DDT.

What should be noted in the results is the improvement in DDT performance when the accent of the test material was switched from the American accent to the South African accent. This was made evident by the increase in means and a drop in both the range and standard deviations. These values alone suggest an improvement in the dichotic digit scores of South African adults when the stimulus was switched from an American English accent to a South African English accent. Furthermore, the data show the minimum score improving from 75% (American accent 2-pair DDT) to 90% (SA accent 2-pair DDT) showing cases of false positives in the former and none when the accent was corrected for in the latter. This suggests that South African participants perform better on the 2-pair DDT when the test is in a South African accent.

As the data were not normally distributed, the researcher proceeded with non-parametric data analyses to determine if there was a statistically significant difference between the 2-pair DDT scores for South African adults when the test was presented in an American accent versus a South African accent. A Wilcoxon signed ranks test was done to compare

the data collected when using the original American accent and the South African accent 2-pair DDT. The test was chosen as it tests for the statistical comparison of the average of two dependent samples (Trochim & Donnelly, 2001).

A z-statistic value of -5.117 was calculated in the right ear and -4.404 in the left ear. These values show big variations between the mean scores obtained with the American accent 2-pair DDT and the South African accent 2-pair DDT. Bilateral p-values of 0.00 were found when comparing the American accent 2-pair DDT scores and the SA accent 2-pair DDT scores. These values are less than the significance level 0.05 alpha values. A Bonferroni correction was done to assess the possibility of a type 1 error, i.e. rejecting the hypothesis when it is in fact true. Corrected p-values were 0.00 bilaterally, which is still less than the 0.05 significance level and thus, the null hypothesis can be rightfully rejected. This result shows that the South African adult performs better on the 2-pair DDT when the stimulus recording is in a South African accent.

The data from the study was further analysed to test if there was a statistically significant difference between the South African English first language speaker and the South African English second language speaker on the South African accent 2-pair DDT. Table 6 shows a summary of the results.

Table 6: The 2-pair DDT scores of the South African English first language speaker versus the South African English second language speaker

	South African English first language speaker		**South African English second language speaker**	
	Right ear	**Left ear**	**Right Ear**	**Left ear**
Mean	98.01	98.01	97.25	97
Standard deviation	2.98	3.01	3.24	3.16
Range (minimum-maximum)	10 (90-100)	10 (90-100)	10 (90-100)	10 (90-100)
Skewness	-1.36	-1.81	-0.85	-0.88
Kurtosis	0.81	2.45	-0.56	-0.21
Shapiro-Wilk test	0	0	0	0

When comparing the South African English first language speaker and the South African English second language speaker on the South African accent 2-pair DDT, the former achieved a skewness of -1.36 (kurtosis=0.81) for the right ear and -1.81 (kurtosis=2.45) for

the left ear. The latter group showed a skewness of -0.85 (kurtosis=-0.56) for the right ear and -0.88 (kurtosis=-0.21) for the left ear. The findings in Table 6 show that the data were skewed to the left and that there were few outliers.

A Shapiro-Wilk test revealed a score of 0 bilaterally, which indicates that the data were not normally distributed. As a result, a Wilcoxon signed ranked test was done to compare the two groups and a z-statistical value of -0.8 and -1.33 were found in the right ear and left ear respectively. The scores were both close to -1.0. The z-values show that the scores of both South African English first language and second language speakers were close to the mean score with little variation between the two groups. P-values of 0.42 and 0.18 were calculated for the right ear and left ear. These values are greater than the alpha value 0.05 and thus the null hypothesis is accepted. It can thus be concluded that there is no statistically significant difference between the performance of South African English first and second language speakers on the South African accent 2-pair DDT. The current study has a large sample size of 84, which reduces the chances that the above finding presents a type 2 error, i.e. accepting the null hypothesis when it is false (Trochim & Donnelley, 2001)

Aim 3: To collect preliminary normative data for both the American 2-pair DDT and the newly recorded South African 2-pair DDT from South African English-speaking adults.

The means and standard deviations calculated in Aim 2 were used to generate preliminary normative data for South African Adults on the 2-pair DDT. These results are summarised in Table 7.

Table 7: Preliminary normative data for South African Adults (18-62 years) on the dichotic digit test

	American accent test scores (percentages)		**South African accent test scores (percentages)**	
	Right ear	**Left ear**	**Right ear**	**Left ear**
Range	75-100	75-100	90-100	90-100
x ±SD	94.07±5.39	94.91±5.64	97.65±3.11	97.53±3.11
x-2SD	83.29	83.63	91.43	91.31

Key:
x= arithmetic mean
SD=standard deviation

Table 7 shows a summary of the data collected from participants on both the American accent 2-pair DDT and the new South African accent 2-pair DDT (the preliminary

normative data). For the American accent 2-pair DDT, the range of the scores was 75% to 100% bilaterally. The mean values (x) were 94.07% and 94.91% for the right ear and left ear respectively. The standard deviations were 5.39% in the right ear and 5.64% in the left ear. The means were high but, upon calculating two standard deviations below the means (x-2 SD), the values drop to 83.29% in the right ear and 83.63% in the left ear. These values were lower than their American counterparts of x=97.8% (SD=2.9) for the right ear, 96.5% (SD=1.7) and x-2SD=90% bilaterally (Saleh et al., 2003) which suggests that the South African adult, reporting no symptoms of CAPD or showing no signs of CAPD, has an abnormal dichotic listening performance.

For the South African accent 2-pair DDT, the participants' scores were in a range of 90% to 100%. The mean values (x) were 97.65% (SD=3.11) and 97.53% (SD=3.11). Upon calculating two standard deviations below the means (x-2 Std.Dev), the values drop to 91.43% in the right ear and 91.31% in the left ear. The South African accent 2-pair DDT results were comparable to the findings from their American counterparts cited in the paragraph above which suggests this is a more accurate 2-pair DDT score/reflection of dichotic listening ability.

CHAPTER 5 DISCUSSION

5.1 Introduction

This chapter discusses the current study findings in relation to the aims. The discussion relates the findings of the current study to previous literature and articulates the potential implications of the current study findings.

5.2 Adapting the 2-pair DDT

The developmental design used to achieve the first aim of the study – adapting the 2-pair DDT to be more appropriate for the South African context – produced a 2-pair DDT where the stimulus was in a South African English accent. As the test stimulus matched the accent of the target population, results from this test may serve as a more accurate reflection of the South African adult's dichotic listening ability. The qualitative feedback from the participants, who found the South African accent 2-pair DDT recording to sound more human like and realistic, supports this statement. To the participants, the adapted test was more realistic in relation to the language they listen to in everyday situations and thus more appropriate to use for testing. The former statements are supported by research done by Rajabpul et al. (2014) where they developed a Persian single DDT. Upon administering the test to Persian speaking male students aged 7–9, they concluded that the test was more appropriate to assess the Persian speaking population and it had a high test-retest reliability. A similar conclusion was drawn by Shahmir et al. (2015) where they developed a Persian double dichotic digit test and administered it to Persian speaking girls aged 7–11. In clinical practice, as the possibility of a linguistic bias has been minimised, South African clinicians can potentially have more confidence that a South African examinee's performance on the South African accent 2-pair DDT is their genuine dichotic listening ability. This will in turn strengthen the clinician's confidence in the diagnosis and an appropriate management plan may be devised.

When it comes to adapting a CAPD test, studies like that of Rajabpul et al. (2014) and Shahmir et al. (2015), included a description of how they developed the Persian versions of dichotic tests. Similar to the current study, the speaker used in the recordings was a male who spoke the language of the target population (Persian), a radio station was used to record the test and multiple recordings were done from which the best was chosen to be

included in the test. However, the studies' description of the test development was specific to that test, focusing on the technical aspects of production, and does not show how similar CAPD tests could be modified to suit the needs of a specific context. Cameron et al. (2016) also included a description of how an Australian dichotic digit difference test was developed. Similar to the aforementioned article, a male Australian English accent speaker was chosen to record the test, multiple recordings were made and the recording took place in a soundproof environment. The study's description of the development is also specific to the test being developed and does not provide a description of the general development process.

In contrast, the developmental study design used in the current study is not limited to the 2-pair DDT. The stages described and applied could potentially be used to adapt other CAPD tests or similar tests to suit the needs of a specific context. This has promising implications for the adaptation of tests contained in the Tonal and Speech Material for Auditory Perceptual Assessment Disc 2.0, including language-based tests, to make it more appropriate to the South African context. This proposition is particularly significant as South Africa has 11 official languages. If all the tests could be adapted to be more contextually appropriate, South African patients presenting with CAPD symptoms could receive a more valid and comprehensive assessment that leads to an accurate diagnosis, and a proper management plan. Furthermore, as issues surrounding the validity and applicability of CAPD tests are not unique to South Africa, the developmental study design may prove invaluable to other countries who wish to adapt CAPD or similar tests.

5.3 Effect of accent on dichotic digit test performance

The below normative data, by 10.37% in the in the left ear and 6.61% in the right ear, scores on the American accent DDT suggest that normal hearing South African English speaker presents with an abnormal dichotic listening performance. This is despite them reporting no CAPD symptoms or a history that may indicate a reduced dichotic listening performance. The results are thus regarded as false positives.

These findings are consistent with a previous study done by Saleh et al. (2003) which also showed that South African adults perform worse on the 2-pair DDT when compared to their American counterparts. However, the current study findings show a worst-case scenario difference of 10.37% as opposed to the 23.6% found by Saleh, et al. (2003). This

is a difference of 12.9 % when compared to the current study's worse performing ear (left). The differences in the scores could be due to current study's larger sample size of 84 participants as opposed to 32 participants by Saleh at al., (2003). The study by Saleh at al., (2003) assessed more than the dichotic listening but, it was the first test administered thus participant fatigue is an unlikely factor. In all other considered aspects, the current study and the Saleh et al. (2003) study are similar; the participants' profiles were similar, the study design and procedure for 2-pair DDT assessment were also similar. The results for both studies suggest that the use of the American accent 2-pair DDT and normative data could lead to false positives.

When the DDT was presented using a South African accent, i.e. when using the South African accent 2-pair DDT recordings, an overall improvement was evident. The means elevated to the high 90%, the standard deviations dropped bilaterally and none of the participants scored below 90%. Even when applying the 2-standard deviations below the mean, the score was still above 90%. Furthermore, the mean values were comparable to the Bellis (2003) norms regarded as international standards of 90% (Saleh et al., 2003), suggesting that this was a true normal performance by the South African participants. The smaller standard deviation values in the current study are indicative of a smaller standard of error, which suggests that the study findings, i.e. the dichotic listening performance of the sample, is close to that of the population from which it was sampled (Trochim & Donnelly, 2001). This supports possible generalisation of the findings.

The statistical analysis showing improvement in DDT scores when the stimulus accent is switched from American to South African suggest that that the 2-pair DDT is affected by accent. These results are consistent with the findings of Saleh et al. (2003) which suggested that the 2-pair DDT carries a linguistic bias. This can further imply that the more language heavy tests like PSSI will be more so affected. This will greatly disadvantage South Africans taking the CAPD test. The results further support that the use of the American accent 2-pair DDT could lead to false positives.

False positives from using the American accent 2-pair DDT could have adverse effects on a patient and their families (Poulakis, Barker & Wake, 2003; Khairi, Rafidah & Affizal et al., 2011: Brodersen & Sierma, 2013). False positive results can lead to a patient having anxiety and stigmatisation and the patient would have the unfair labelling of a CAPD that they do not have (Khairi et al., 2011). Ethically, this goes against the principles of

beneficence and non-maleficence. Children would have to grow up in the false knowledge that they have a disorder. Their upbringing would include therapy, which takes time from the child, clinician and family. Therapy time would come at the expense of play time (necessary for normal development), and even school time. In addition, resources would be spent by the family to travel for therapy, to access assistive devices and for home programmes that are often designed to maximise therapy. This is particularly a problem in South Africa, a developing country where 29.1% of the population lives in poverty and that percentage comprises mostly Black people (Pascoe and Norman, 2011; Statistics South Africa, 2017). Resources would also be unnecessarily spent by hospitals catering for a falsely diagnosed pathology. This is again a big problem in South Africa as very little financial focus is placed on Audiological services and rehabilitation as a whole due to the overwhelming occurrences of diseases like tuberculosis, HIV and non-communicable diseases (Pascoe & Norman, 2012: Fouche-Copley, 2016). Furthermore, this would place a burden on the provision of CAPD services in South Africa. Most audiologists do not feel competent in CAPD which leaves few audiologists who can work with patients with a CAPD. This may result in delayed services and long waiting periods for assistive devices and services (Fouche-Copley, 2016).

In the presence of a positive diagnosis, parents often report feelings of fear of what could happen: delayed developmental milestones, lack of speech development, low academic performance, no employment and inability to make friends (Paulakis et al., 2003; Khairi et al., 2011). Diagnosis of CAPD by using the American accent 2-pair DDT or even other American accent tests could unnecessarily cause the above effects. Research has found that even when the diagnosis has been reversed or the parents have been informed that it was a false positive, the parents may continue worrying about their child's hearing (Khairi et al., 2011).

Comparison between the South African English first and second language speakers showed no statistically significant differences between their performance on the South African accent 2-pair DDT, which supports the use of the test to assess both South African English first and second language speakers as it has no bias against either group. It further suggests that the recognition rate of the South African white accent is similar between the groups and that the same accent may be used to adapt future CAPD or other speech tests.

5.4 Generating preliminary normative data

The normative data collected when using the American accent 2-pair DDT were low in comparison to the internationally recognised normative data by Bellis (2003) as reported by Saleh at al. (2003). Saleh et al. (2003) also reported lower preliminary normative data for the 2-pair DDT in their study. This would support findings in Aim 2 that suggest the American accent 2-pair DDT is not appropriate for use in South Africa. In contrast, the normative data collected from the South African accent 2-pair DDT recording were comparable to the international norms. This is particularly significant as the test material accent matched the sample being investigated. It is widely accepted that the pass criteria for the 2-pair DDT is 90% (Saleh et al., 2003). With the current research yielding similar normative data, the researcher recommends the South African accent 2-pair DDT normative data as a true reflection of the South African population's performance on the former test.

However, the newly developed 2-pair DDT and norms are yet to be validated. Thus, in the interim, the researcher proposes that the current study's normative data on the American accent 2-pair DDT be used to interpret test scores.

5.5 Study limitations

The study used convenience sampling and snowball. Convenience sampling is susceptible to sampling error and selection bias while snowball sampling does not guarantee sample representativeness. These forms of sampling helped achieve the study aims but they limited the ability to generalise the study findings.

Participants in the study were between 18 and 62 years of age. While the information is invaluable, it cannot be applied to individuals below the age of 18.

While the study included a short section where the participants could comment on the DDT not every participant made a comment. The question may not have been engaging enough to get a response from all participants.

The study adapted the 2-pair DDT to a South African English accent, a white English accent. South Africa has more than one English accent and 11 official languages. This can bring into question the applicability of the 2-pair DDT for other English accents or other

languages; more so when considering that non-English-speaking children only learn English in primary school.

The study did not investigate if the 2-pair DDT is reliable.

CHAPTER 6 CONCLUSION

The current study findings suggest that the way the developmental design was structured and how it was incorporated in the current study, CAPD test or other similar tests could potentially be adapted using this process. Adapting these tests would not only help to contextualise the current protocol used to assess for CAPD in South Africa but could pave the way for a more comprehensive test battery. This is important as 95% of the tests used to assess for CAPD have a high linguistic load and are in need of adaptation for the South African context (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; ASHA, 2005; Fouche-Copley et al., 2016). At present, the SA CAPD protocol uses low linguistic loaded stimuli that do not comply with the recommendations set forth by ASHA (2005). The protocol does not assess the full communication needs of the South African population; it includes mainly non-verbal stimuli and only has word stimuli (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; ASHA, 2005; Fouche-Copley et al., 2016). ASHA stipulates that assessment for CAPD should include several aspects of auditory processing to accurately reflect integrity of the CANS (South African CAPD Taskforce, 2000; South African CAPD Taskforce, 2001; Saleh et al., 2003; Campbell & Wilson, 2003; ASHA, 2005; Fouche-Copley et al., 2016). The findings from this study are promising for the future of CAPD in South Africa when comes contextualising test material, i.e. the researcher believes that the developmental design used in this study can be used to adapt more tests to be contextually appropriate.

The study further showed evidence that the American 2-pair DDT currently used for CAPD assessment in South Africa carries a linguistic bias against the South African English speaker. Results also suggested that the American normative data are not appropriate for use in South Africa. This is particularly worrisome as diagnostic decisions are made based on the results of this test which indicates the possibility of false positive diagnoses being made. Furthermore, the latter test produced results that were within normative range and the gathered preliminary normative data were comparable to international standards or Bellis (2003) norms. This suggests that the South African accent 2-pair DDT and norms are more appropriate for use in South Africa, which supports the need to adapt more tests to be contextually appropriate.

The current study has successfully incorporated a developmental study design to adapt a 2-pair DDT that can potentially be used clinically in South Africa. The test produces results that meet the pass criteria and the corresponding preliminary normative data meet international standards set by Bellis (2003). While formative evaluations were positive, which indicated that the test is more appropriate for use in South Africa, the test and norms still need to be validated before they may be used clinically in South Africa.

CHAPTER 7 RECOMMENDATIONS

1 While the study produced a South African 2-pair DDT, the test cannot be used clinically before it is validated for use in South Africa. Currently a team of honours degree students from the University of Cape Town is investigating the test-retest reliability of the South African accent 2-pair DDT. The sensitivity and specificity of this test still need to be established.

2 The current study focused mainly on adapting the 2-pair DDT from an American English accent to a South African English accent. While this is a good start, it would be beneficial to the South African context if the test were to be developed for other languages in South Africa. According to the South African Government, as of 2016 only 8.3% of the South African population speak English as a home language/first language. This means a greater 91.7% are not English first language speakers. This is particularly important as CAPD is often identified in primary school ages. The majority of South African children are only being introduced to the English language in primary school and this test would not be valid if it was being administered to an individual who does not speak English.

3 The study needs to be replicated for English speaking groups younger than 18 years of age to ascertain if accent affects DDT performance in younger ages and to collect normative data for use in clinical settings. This could potentially help identify and manage CAPD earlier.

4 The current study presented a process that may be used for adapting tests to meet a specific context. It would work in the interest of CAPD provision and Audiology in South Africa if future studies could focus on adapting more tests from the Tonal and Speech Material for Auditory Perceptual Assessment Disc 2.0. In this way, comprehensive test batteries may be chosen as recommended by ASHA 2005 when assessing patients for CAPD.

5 The participants in the current study were observed to show some signs or stress or anxiety during the testing. Some even reported that both the South African accent 2-pair DDT and DVA specified 2-pair DDT induced stress. This is an important observation as ASHA (2005) reports that this can impact or confound CAPD test performance. More research is needed to see the extent to which the test induces anxiety and whether that affects 2-pair DDT performance, particularly in populations younger than 18 years old.

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APPENDICES

Appendix A: Low Linguistically Loaded Central Auditory Processing Disorders Test Protocol

The recommended "Low linguistically loaded central auditory processing test protocol" included the following tests for people proficient in English:

For screening:

- Checklists (CHAPPS, Fisher's Auditory Problems Checklist)
- Screening tests for children (SCAN (3–11 years), SCAN-A (Adolescents), SAAT (4–8 years).

For behavioural diagnostic testing:

- The Paediatric Peach Intangibility test (PSI) for children younger than 8 years old.

For older children and adults one test from each category:

- Dichotic listening (1 Linguistically loaded test and 1 non-linguistically loaded test), eg: Dichotic digits test, Dichotic consonant vowel test, Staggered Spondaic Word test, Competing sentence test, Synthetic sentence identification test, Dichotic speech identification tests, SCAN, Dichotic Rhyme test.
- Temporal ordering test, eg: Pitch Pattern Sequence test, Duration Pattern test, Psychoacoustic Pattern Discrimination test.
- Monaural low redundancy test, eg: low pass filtered speech, time compressed speech, time compression plus reverberation, SSI ICM, Speech in noise tests.
- Binaural fusion test, eg: Band-pass filtered binaural fusion test, Consonant-vowel-consonant binaural fusion test, MLD, RASP and Interaural just noticeable differences.

Until such time that more contextually appropriate test material is developed, the following test were recommended for and individual who is not very proficient in English:

Electrophysiological measures:

- ABR

- AMLR
- P300
- MMN

Behavioural measures:

- Dichotic digits test
- Frequency Patterns or the Pitch Pattern Sequence test
- Duration pattern test
- Psychoacoustic Pattern Discrimination Test
- Masking Level Difference test

Source: South African *CAPD Taskforce* (2001)*: An update.*

Appendix B: Ethics approval letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6626
Email: shuretta.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

26 September 2018

HREC REF: 620/2018

Ms T Cloete
Communication Sciences and Disorders
Health & Rehab

Dear Ms Cloete

PROJECT TITLE: THE PERFORMANCE OF SOUTH AFRICAN ENGLISH ADULT SPEAKERS ON THE 2-PAIR DICHOTIC DIGITS TEST RECORDED IN A SOUTH AFRICAN ACCENT (MSc Candidate - Mr S. Segoneco)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 September 2019.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

The HREC acknowledge that the student, Selekisho Segoneco will also be involved in this study.

Yours sincerely

Signature Removed

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2006), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines.
The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

Appendix C: Permission to conduct study on students

	RESEARCH ACCESS TO STUDENTS	DSA 100

NOTES

1. This form must be **FULLY** completed by all applicants who want to access UCT students for the purpose of research or surveys.
2. Return the fully completed **(a) DSA 100** application form **by email**, in **the same word format**, together with **your: (b) research proposal inclusive of your survey, (c) copy of your ethics approval letter / proof (d) informed consent letter** to: Moonira.Khan@uct.ac.za. You application will be attended to by the Executive Director, Department of Student Affairs (DSA), UCT.
3. The turnaround time for a reply is **approximately 10 working days.**
4. NB: It is the responsibility of the researcher/s to apply for and to obtain **ethics approval and to comply with amendments that may be requested;** as well as **to obtain** approval to access UCT staff and/or UCT students, from the following, at UCT, respectively: (a) **Ethics:** Chairperson, Faculty Research Ethics Committee' (FREC) for ethics approval, (b) **Staff access:** Executive Director: HR for approval to access UCT staff, and (c) **Student access:** Executive Director: Student Affairs for approval to access UCT students.
5. **Note:** UCT Senate Research Protocols requires compliance to the above, **even if prior approval has been obtained from any other institution/agency. UCT's research protocol requirements applies to *all* persons, institutions and agencies from UCT and external to UCT who want to conduct research on human subjects for academic, marketing or service related reasons at UCT.**
6. **Should approval be granted to access UCT students for this research study, such approval is effective for a period of one year from the date of approval (as stated in Section D of this form), and the approval expires automatically on the last day.**
7. **The approving authority reserves the right to revoke an approval based on reasonable grounds and/or new information.**

SECTION A: RESEARCH APPLICANT/S DETAILS

Position	Staff / Student No	Title and Name	Contact Details (Email / Cell / land line)
A.1 Student Number	SGNSEL001	Mr Selekisho Segoneco	Selekisho.Segoneco@uct.ac.za / 0715463259
A.2 Academic / PASS Staff No.	01462058		
A.3 Visitor/ Researcher ID No.			
A.4 University at which a student or employee	University of Cape Town	Address if *not* UCT:	
A.5 Faculty/ Department/School	Faculty of Health Sciences: Department of Health and Rehabilitation Sciences		
A.6 APPLICANTS DETAILS If different from above	Title and Name	Tel.	Email

SECTION B: RESEARCHER/S SUPERVISOR/S DETAILS

Position	Title and Name	Tel.	Email
B.1 Supervisor	Mrs Tracey-Lee Cloete	+27 21 406 6059	Tracey-Lee.Cloete@uct.ac.za
B.2 Co-Supervisor/s	Mrs Lucretia Petersen	+27 21 406 6993	Lucretia.Petersen@uct.ac.za

SECTION C: APPLICANT'S RESEARCH STUDY FIELD AND APPROVAL STATUS

C.1 Degree – if applicable	Masters in Audiology (full dissertation)
C.2 Research Project Title	The performance of South African English Adult speakers on the 2-pair dichotic digits test recorded in a South African English accent.
C.3 Research Proposal	Attached: Yes ■ No □
C.4 Target population	Students Ages 18-65
C.5 Lead Researcher details	If different from applicant: 01412020, Mrs Tracey-Lee Cloete, 021 406 6059, Tracey-Lee.Cloete@uct.ac.za
C6. Will use research assistant/s	Yes □ No ■ If yes- provide a list of names, contact details :
C.7 Research Methodology and Informed consent	Research methodology: Descriptive-comparative qualitative, hearing tests Informed consent: Yes, advised to participants
C.8 Ethics clearance status from UCT's Faculty Ethics in Research Committee /Chair (EiRC)	Approved by the UCT EIRC: Yes ■ With amendments: Yes □ No ■ (a) Attach copy of your UCT ethics approval. Attached: Yes ■ No □ (b) State date / Ref. No / Faculty of your UCT ethics approval: 26/09/2018 Ref. /Faculty.: 620/2018

SECTION D: APPLICANT/S APPROVAL STATUS FOR ACCESS TO STUDENTS FOR RESEARCH PURPOSE

(To be completed by the UCT - ED, DSA or Nominee)

	Approved / With Terms / Not	* Conditional approval with terms	Applicant/s Ref. No.:
D.1 APPROVAL STATUS	(i) Approved ■ ~~(ii) With terms~~ ~~(iii) Not approved~~	a) Access to students for this research study must only be undertaken after written ethics approval has been obtained. b) In event any ethics conditions are attached, these must be complied with before access to students.	SGNSEL001/01462058 / Mr Selekisho Segoneco

D.2 APPROVED BY:	Designation	Name	Signature	Date of Approval
	Executive Director Department of Student Affairs	*Dr Moonira Khan*	Signature Removed	*18 October 2018*

Appendix D: Permission to conduct study on staff

HR194	ACCESS TO UCT STAFF FOR RESEARCH PURPOSES	UNIVERSITY OF CAPE TOWN IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

NOTES

- Forms must be downloaded from the UCT website: http://forms.uct.ac.za/forms.htm
- This form must be completed by applicants who are requesting to access UCT staff for the purpose of research.
- A copy of the research proposal as well as the Ethics Committee approval must be attached.
- It is the **responsibility of the researcher/s to apply for ethical clearance** from the relevant Faculty's Research in Ethics Committee (RiEC).
- If you are requesting staff information, you are required to complete the HR Information Request Form (HR190) and submit it together with all the required documentation.
- The turnaround time for a reply is **approximately 10 working days unless specified as urgent.**
- Return the completed application form and all the above documentation to Joy Henry via email: joy.henry@uct.ac.za; or deliver to: For the Attention: Executive Director, Human Resources Department, Bremner Building, Room 214, Lower Campus, UCT.

SECTION A: APPLICANT DETAILS

Title	Mr	Name	Selekisho Segoneco
Telephone number	+27 21 406 6313	Email address	selekisho.segoneco@uct.ac.za
Student number	sgnsel001	Staff number	01462058
Visiting researcher ID / passport number	N/A		
Faculty Officer contact details	Faculty of Health Sciences		
University or institution at which employed or a registered student	University of Cape Town		
Faculty or department in which you are registered or work	Department of Health and Rehabilitation		
Address (if not UCT)			

SECTION B: SUPERVISOR DETAILS

	Title and name	Telephone number	Email address
Supervisor	Mrs Tracey-Lee Cloete	+27 21 406 6059	Tracey-Lee.Cloete@uct.ac.za
Co-Supervisor	Lucretia Petersen	+27 21 406 6993	Lucretia.Petersen@uct.ac.za

SECTION C: APPLICANT'S FIELD OF STUDY (if applicable) / TITLE OF RESEARCH PROJECT / STUDY

Degree	Masters Degree in Audiology	
Research project or title	The performance of South African English Adult speakers on the 2-pair dichotic digits test recorded in a South African English accent.	
Research proposal attached	☒ Yes	☐ No
Target population (number of UCT staff)	Sample required	
Amount of time required for an interview and/or questionnaire	45-60 minutes	
Lead Researcher details	Selekisho Segoneco (Contact details above)	
Proof of ethical clearance status attached	☒ Yes	☐ No

SECTION D: FOR OFFICE USE (Approval status to be completed by the Executive Director, Human Resources or Nominee)

Support or approval			Role	Signature	Date
Supported?	☑ Yes	☐ No	Joy Henry (Office Co-Ordinator)	Signature Removed	16/10/2018.
Approved?	☑ Yes	☐ No	Miriam Hoosain (Executive Director: HR)		17/10/18

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Appendix E: Recruitment Letter

Dear Students,

Are you between the ages of 18 and 65? Are you a healthy adult with normal hearing?

If so, you are needed for a study that aims to investigate how a change in the stimulus accent of a test known as the 2-pair dichotic digit (2-pair DDT) American accent to a South African accent will affect test performance.

Study outline

I am an Audiology Masters Student currently researching how a difference in the accent of the 2-pair DDT; a test that looks at how our ears can process different information presented at the same time, could affect test performance. This study will provide data that could assist in more appropriate assessment, identification and management of what is known Central Auditory Processing Disorders in the context of South Africa. It can potentially show how more tests that are affected by accent can be adapted to fit the population of interest.

You will be required to attend **a session** at the Audiology Research Laboratory, **E48 Room 12**, **Old Main Building**, Groote Schuur Hospital. The session will be broken down into two parts. Part one involves the assessment of your **hearing** i.e. **your middle and inner ear functioning** will be assessed. Part two involves the assessment of your dichotic listening; our ability to make sense of to two different information presented to the ears simultaneously. The session will take approximately 60 minutes. **None of these tests are invasive or harmful.**

Anyone interested in participating should:

- be above 18 years old.
- think they have normal hearing.
- have no history head and neck injuries, no history of hearing loss.
- no symptoms of processing difficulties.
- no exposure to loud noises 24 hours prior to the assessment

- be currently not taking any ototoxic medication (eg, TB medication, hypertension, heart failure medication such as, furosemide/Lasix bumetanide or cancer medication such as cyclophosphamide, cisplatin, and bleomycin. etc.)

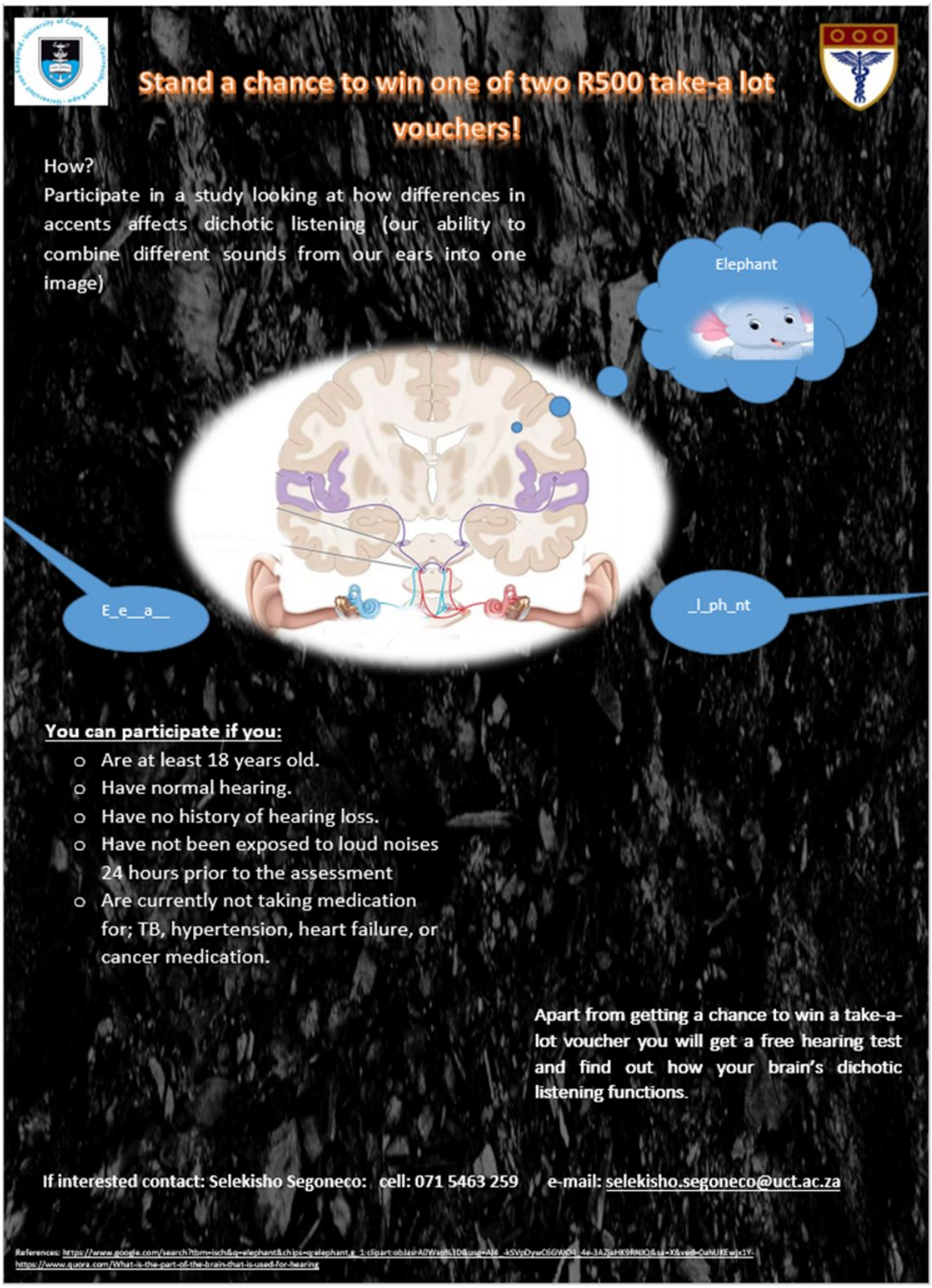
The benefits of taking part in the study include having a free hearing test and finding out how your brain's dichotic listening functions. Furthermore, you will be entered into a lucky draw to win one of two R500 Takealot vouchers.

Deadline for signing up: (pending)

If you are interested in participating in this study, and require additional information, please contact:

Selekisho Segoneco **Cell: 071 5463 259** **email:** selekisho.segoneco@uct.ac.za

Appendix F: Study Poster



Appendix G: Study record sheet

Participant number: _____

Age: _____

Sex: _____

Test Date: _____

Audiologist: _____

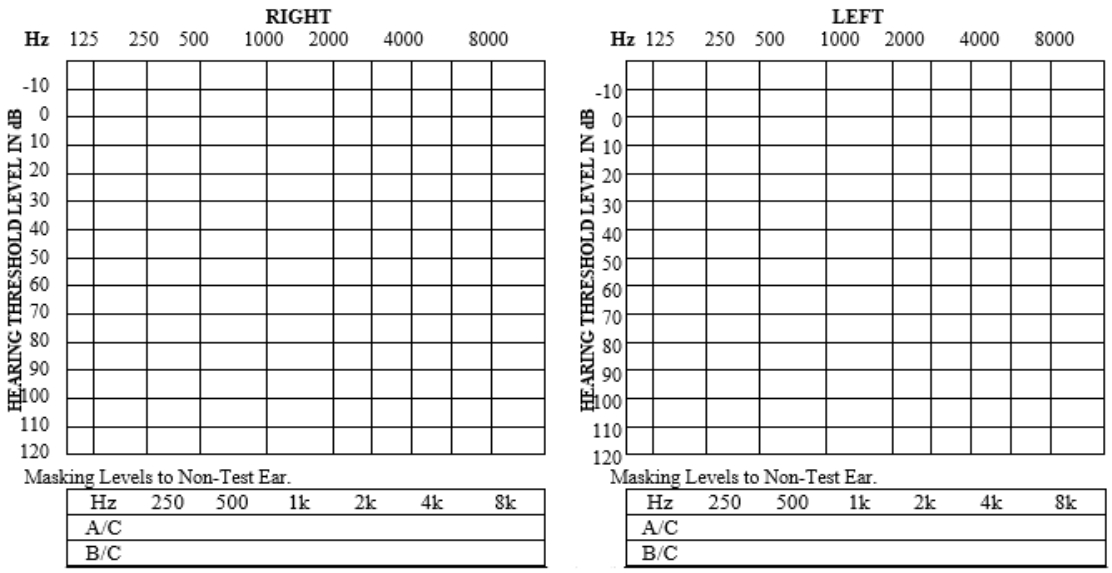
Audiometer: _____

Test Reliability: _____

Pure Tone Average: Right _____dB

Left _____dB

Pure Tone Audiogram



SRT: Right _____dB Left _____dB	PI-PB: Right ____dB min % _____dB max % dB (masking) M Left ____dB min % _____dB max % dB (masking) M

Tympanometry

	Type	ECV	MI	daPa
Right				
Left				

Acoustic reflex thresholds

	CONTRA		IPSI		IPSI		CONTRA	
	dB	Hz	dB		dB	Hz	dB	
Sound To Right								Sound To Left

Otoscopy: Right: _____

Left: _____

Two-Pair Dichotic Digits

Original American Accent: Right _____% Left_____%

Newly developed South African Accent: Right_____% Left_____%

Perceived difference between the two tests:

_____

_____

Appendix H: Information Sheet

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders, Nursing and Midwifery, Occupational Therapy, Physiotherapy

F45 Old Main Building, Groote Schuur

Observatory, Cape Town, W Cape, 7925

Tel: +27 (0) 21 406 6628/ 6428/ 6534

Fax: +27 (0) 21 406 6323

www.dhrs.uct.ac.za

Dear Participant

My name is Selekisho Segoneco, I am an Audiology Masters student from the University of Cape Town. I am currently conducting a study that aims to improve the applicability of a clinical test used to assess central auditory process, what the brain does with what we hear.

Why am I doing this research?

I am evaluating and adapting a test known as the two-pair dichotic digits test (2-pair DDT). The 2-pair DDT test is a test that assesses how our ears can listen to two numbers presented to each ear at the same time using headsets. The only tests that are available were made in America. I am trying to see how we can adapt this test for the South African context to make it more appropriate when testing South African English speakers.

What happens if I decide to take part in the study?

Should you agree to take part in this study, the following will happen:

You will be given a form to sign to indicate that you are willing to participate in this study and that you understand what is expected of you as a participant in the study.

The procedure will follow two stages:

Part 1: assessing your hearing, i.e. your outer ear will be examined, and your middle and inner ear functioning will be assessed. This will happen as follows.

1 Case history – *you will be asked questions about your hearing and history of hearing loss and ear diseases*

2 Otoscopy – *the researcher will then look into your ear using an otoscope (a specialized torch for looking into the ear canal). This is done to make sure that your ears are suitable for hearing tests; i.e. no ear wax impaction, foreign body or signs of infections in your ear canal and also to see if there are no abnormalities on your ear drum.*

3 Tympanometry – *This test will be done to assess the functioning of your middle ear. The test involves placing a soft probe in your ear and then introduce a bit of pressure into your ear. It is a comfortable test that is routinely done during assessment of hearing so you will not experience any discomfort.*

4 Pure tone audiometry test *i.e. 'hearing test' – you will then be required to undergo a hearing test by listening to a series of tones played in an audiological booth to assess your hearing status.*

5 *After these assessmenst, you will be given feedback about your hearing test results. If you are found to have hearing that is not within normal limits, you will be referred to an audiologist for further management. If the results indicate normal hearing you will proceed to step 2.*

Part: 2

You will now commence to the assessment of your dichotic listening using the two pair Dichotic digits test (2-pair DDT)

1 *You will be required to listen to numbers presented in your ears; two presented in the left ear and two more presented in the right ear simultaneously and report them back. This will be done twice with a 10-minute break in between.*

2 *After these assessments, you will be given feedback about your test results. If you are found to have hearing that is not within normal limits, you will be referred to the 4th year CAPD Audiology clinic for further assessment and management*

What are the risks and benefits of taking part in this study?

This study will not present any risks to you as a participant. All tests and procedures that will be used in this study are routine audiology procedures that have an established safety profile. Participation in the study will put you in a lucky draw to win one of two R500 Takealot vouchers. Furthermore, you will be getting a free hearing test and test of your dichotic listening skill. If any abnormality is detected in your hearing during these assessments, you will be referred to a relevant health professional for further management. The study itself has benefits in the field of Central Auditory Processing Disorders and Audiology in general. It will provide data that could assist in more appropriate assessment, identification and management of Central Auditory Processing Disorders in the context of South Africa and the worldwide field at large.

What if I do not want to take part in this study or if I want to withdraw later?

Participation in this study is completely voluntary. It is completely up to you whether you do or do not participate. Refusal to participate or withdrawal from the study will not have any negative consequence to you. However, your participation is of great value to this study and the potential implications of its findings.

How will my confidentiality be protected?

Please note that none of your personal identifying information will be collected for the purpose of this study. As a participant, you will be assigned a study number that will be used to represent your results in the study. All procedures will be done with you on a one-on-one basis and only the researcher and you will know about the outcome of your assessment. Please note that the data gathered will be used for research purposes only and may be published at the end of the research. As a participant you may request that the data collected not be used in the study and withdraw it at any time. Only the researcher involved

in the study will have access to any information collected about you during this study and this information will be held in a secure locked cabinet here at the University of Cape Town.

How long will it take to participate in this study?

The entire assessment will take 45–60 minutes to complete. While there is no compensation for taking part in the study, you will receive a free full hearing test along with one test of your central auditory processing.

Who can I contact if I have questions about this study?

If you have any questions about this study, please feel free to contact myself Selekisho Segoneco at cell: 071 5463 259, email: Selekisho.Segoneco@uct.ac.za , or my supervisor Tracey-Lee Cloete at Tracey-Lee.Cloete@uct.ac.za.

Should you have any ethical concerns or questions about your rights or welfare as participant please contact the Human Research Ethics Committee:

University of Cape Town Human Research Ethics Committee:
Faculty of Health Science
Human Research Ethics Committee
E52-23 Old Main Building
Groote Schuur Hospital
Observatory
Tel: 021 406 6492
Fax: 021 406 6411

This information sheet, explaining the study, is for you to keep. If you would like a copy of a report on this study, leave and email address a report will be sent. The final results may not be available until a year and a half from now.

Appendix I: Consent form

I, _____hereby agree that the study has been clearly explained to me by the researcher: S. Segoneco. I know that my participation is voluntary. I understand the conditions of this study and that I may withdraw from the study at any time without any implications upon myself. I have had a chance to ask questions and they have been answered to my satisfaction. I have been informed of the benefits of taking part in the study. I understand that the data collected in this study is solely for research purposes and give consent for the researchers to use the data collected. I have been informed that my identity in the study will be kept confidential and I will not be identified in any way. I acknowledge that the contact information of the researcher has been made available to me along with a copy of this consent form.

Appendix J: Case History Guide

Hearing Status questions

1 Do you suspect that you have a hearing loss?

2 Do you ever feel like your hearing is not good on some days?

3 Are you exposed to frequent high levels of noise?

4 Were you exposed to loud noises in the last 24 hours? Music, gunshots or occupation noise?

5 Do you ever notice any ringing, buzzing or roaring in the ears?

6 Does anyone in your family have a hearing loss?

7 Have you ever had your earing tested?

8 Have you ever had any fluid coming from your ears?

9 When last did it happen?

10 Did you see a doctor?

11 Do you ever experience any dizziness or balance problems?

12 Are you currently taking any medication?

13 Do you ever have any trouble following conversations on the phone, in the restaurant, during meetings or in group settings? Please explain.

14 Have you ever been involved in a car accident?

15 Have you ever received any trauma to the head?

16 Have you ever had any surgery on the head or ears?

CAPD questions

1 Do you ever find that you have trouble understanding what people are saying?

2 Do you find that you are sensitive to some sounds? *Explain please.*

3 Do other people ever complain that you cannot hear or understand them well?

4 Do you often need repetition before you understand a statement or an instruction?

5 Are there any subjects you struggled with in school?

6 Do you often struggle to follow long or more than one instruction in series?

7 Are you often forgetful of what people say?

8 Do you ever have difficulty following what is happening on the television?

9 Do you get confused in noisy places?

10 Do you often have to think more or longer about what has been said before you understand?

11 Do you often struggle to hear people in noisy backgrounds?

12 Do you often have trouble remembering information in the order it was said?

13 Do you often find that you have confused words that sound similar?

14 Do you find that you hear better when you are facing the speaker?

15 Do you have trouble memorizing things?

16 Do you often forget things that have just been said?

17 Do you often have trouble telling where a sound is coming from?

Questions guided by Columbus questionnaire, retrieved on 06/07/2018 https://www.columbusspeech.org/wp-content/uploads/2017/08/Audiology-Adult-Case-History-1.pdf as well as Audiology Foundation of America Balance and Hearing Institute, retrieved on 06/07/2018 from https://www.atsu.edu/afainstitute/documents/AuditoryProcessingAPDPacketAdult.pdf .

Appendix K: 2-Pair DDT specifications

Track 3 (2-pair digits) (2:08)

	Time	Left Ch.	Right Ch.
1.	0:01	4,3	1,6
2.	0:05	3,1	9,10
3.	0:11	9,6	1,5
4.	0:16	2,10	6,8
5.	0:21	4,8	6,9
6.	0:26	9,1	10,2
7.	0:31	2,4	9,10
8.	0:36	1,9	8,6
9.	0:42	2,4	3,9
10.	0:47	1,4	10,5
11.	0:52	2,5	1,3
12.	0:57	4,5	2,6
13.	1:02	3,10	5,6
14.	1:08	4,1	9,5
15.	1:13	4,5	3,8
16.	1:18	9,5	4,1
17.	1:23	4,5	10,2
18.	1:28	9,8	3,4
19.	1:33	9,10	8,5
20.	1:39	8,6	4,1
21.	1:44	6,8	10,2
22.	1:49	9,1	2,8
23.	1:55	6,9	3,1
24.	2:00	1,2	3,9
25.	2:05	5,3	2,1

Key: Left Ch = Left Channel

Right Ch = Right Channel

Source: *DVA (1998). Tonal and Speech Materials for Auditory Perceptual Assessment Disc 2.0.*

Appendix L: CAPD test Categories

The following is a list of all four categories. It should be noted that the presented categories are not inclusive of all tests.

1. Dichotic speech tests assess dichotic listening, the ability to process different stimuli presented to each ear (Chermak & Musiek, 2007; Bellis, 2011). The following tests are classified under this category:

i) Dichotic Digits Test (DDT) – Two different digits are presented simultaneously, one to each ear (dichotically). The digits used in the test range are from 1 to 10 with 7 being excluded. The test may be used as binaural interaction test or a binaural separation test. In binaural integration, the listener presents the numbers back in any order while in binaural separation, the listener reports which number pair was presented to each ear.

ii) Dichotic Consonant-Vowel (CV) Test – Single CV segments (i.e. *pa, ta, ka, ba, da, ga*) are presented to each ear in a dichotic listening task and the listener is asked to choose both segments heard from a printed list.

iii) Staggered Spondaic Word Test (SSW) – Listeners repeat spondaic (containing two syllables) words whose onsets are staggered between the two ears such that the last half of the first word and first part of the second word are dichotic while remaining portions are presented in isolation to opposite ears.

iv) Competing Sentences Test (CST**)** – Two different sentences are presented simultaneously, one to each ear; the target sentence is at 35 dB SL (quieter) while the competing sentence is at 50 dB SL (louder).

v) Synthetic Sentence Identification Test with Contralateral Competing Message (SSI-CCM) – Sentences (i.e. 10 nonsense-like) are presented to the target ear while a competing message consisting of continuous discourse is presented to the contralateral ear. The listener is required to choose from a printed list which of the 10 sentences was heard.

vi) Dichotic Sentence Identification Test (DSI) – This test uses the SSI-CCM sentences presented dichotically and requires the listener to identify both sentences heard from a printed list of all 10 sentences.

2. Binaural interaction tests for binaural interaction, the ability to process different but complementary information presented to both ears either sequentially or simultaneously (Chermak & Musiek, 2007; Bellis, 2011). The following tests are classified under this category:

i) Rapid Alternating Speech Perception (RASP) – Listeners repeat simple sentences that alternate every 300 milliseconds between right and left ears.

ii) Binaural Fusion (band-pass filtered) – Listeners repeat spondaic words presented but filtered such that the low frequencies are presented to one ear and the high frequencies to the other ear.

iii) Binaural Fusion (consonant-vowel-consonant/CVC) – Listeners repeat CVC words presented such that the consonants are presented to one ear and the vowel to the other in a sequential fashion.

3. Monaural low redundancy tests assess the ability to achieve closure or fill in missing auditory information and correctly discriminate the stimulus even when part of it is distorted or missing (Chermak & Musiek, 2007; Bellis, 2011). The following tests are classified under this category:

i) Time Compressed Speech – The temporal characteristics of the speech signal are altered by reducing its duration without affecting the frequency characteristics.

ii) Time Compression plus Reverberation – The addition of an echo to the above task further reduces the redundancy of the speech signal.

iii) Synthetic Sentence Identification Test with Ipsilateral Competing Message (SSI-ICM) – Sentences (i.e. 10 nonsense-like) are presented to the target ear while a competing message consisting of continuous discourse is presented to the ipsilateral ear. The listener is required to choose from a printed list which of the 10 sentences was heard.

iv) Low Pass Filtered Speech (LPFS) – Listeners repeat monosyllabic CVC words passed through a filter that rejects energy above 500 Hz (high frequencies); words are presented monaurally.

4. Temporal processing tests for assessing the ability to make a discrimination based on the timing order or pattern of the stimulus (Chermak & Musiek, 2007; Bellis, 2011). The following tests are classified under this category:

i) Frequency Patterns or Pitch Pattern Sequence Test (PPST) – Listeners detect which of three tones presented in succession is a different frequency/pitch.

ii) Duration Pattern Test (DPT) – Like the PPST, except listeners describe verbally the pattern of tones presented (e.g. short-short-long).

iii) Psychoacoustic Pattern Discrimination Test (PPDT) – Listeners discriminate a monaural change in the pattern by pressing a button.